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Instruction Manual

No. E.B.2204

for

18 MHz Oscilloscope
TF 2204

MARCONI INSTRUMENTS LIMITED
ST. ALBANS HERTFORDSHIRE ENGLAND

Q.O.
3.5c

EB 2204
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Chapter 1

General information

Fig. 1.1 18 MHz Oscilloscope TF 2204

1.1 INTRODUCTION

The TF 2204 18 MHz Oscilloscope is a general-purpose, dual-channel, wide-bandwidth instrument. The display is bright and the controls are arranged for ease of operation. Throughout the oscilloscope, silicon transistors and integrated circuits are used to achieve high performance, long-term reliability and low power consumption. Being portable and robust, the oscilloscope is suitable for use in a large range of environmental conditions, and yet it provides the accuracy and versatility required of a laboratory instrument.

1.2 DATA SUMMARY

CATHODE RAY TUBE	Newly-designed, rectangular face-plate employing p.d.a. ratio of 4:1
Minimum screen area	10 x 8 cm.
E.H.T.	4 kV.
Phosphor	P31 medium short persistance.
Internal graticule	Provided as standard in 1 cm and 2 mm divisions.
VERTICAL AMPLIFIERS	Except where indicated, channels 1 and 2 are identical.
Sensitivity ranges	11 ranges - 20 mV/cm to 50 volt/cm. (Increased to 2 mV/cm using X10 switch) Maximum input 500 volt d.c. positive or negative, or peak a.c.
Fine Gain Control	3:1 variable extending range from 2 mV/cm to 150 volt/cm (uncalibrated).
Measurement accuracy	$\pm 5\%$ over the temperature range $\pm 20^{o}$ from setting-up temperature.
Input Impedance	1 MΩ with 35 pF shunt at all input sensitivities.
Bandwidth	D.C. or 3 Hz to 18 MHz (-3dB) at 20 mV/cm dependent on d.c./a.c. switch. (Fine Gain in CAL position). D.C. or 3 Hz to 5 MHz (-3dB) at 2 mV/cm dependent on d.c./a.c. switch. (Fine Gain in CAL position).
Rise time	19 nsecs.
Signal delay	Approximately 170 nsecs.
Y Shift Control	At least 20 cm of shift available, i.e., $2\frac{1}{2}$ times screen depth.
Channel 2 input	Channel 2 signal input can be inverted to allow differential measurements between channels 1 and 2.
Common mode rejection ratio	50:1 at 20 MHz. 500:1 at 50 kHz.
Operating modes	(1) Channel 1 only (2) Channel 2 only (normal or inverted) (3) Alternate channels 1 and 2 (4) Chopped channels 1 and 2 (chopping frequency approximately 400 kHz). (5) Channels 1 and 2 added algebraically

CALIBRATOR	Square wave outputs of 100 mV and 1 volt p-to-p. Amplitude accuracy ±1%. Frequency 1 kHz accuracy ±2%. Rise time less than 1 μsec. Frequency and voltage accuracy maintained under all temperature conditions from -10° to +50°C.
TIMEBASE	
Time measurement	Calibrated sweep speeds - 200 nsecs/cm to 1 sec/cm in 21 ranges 1, 2, 5 sequence. Calibrated switched expansion of x1 and x5.
Non-linearity of sweep	±2%
Sweep rate	2.5:1 variable over the range 200 msecs. to 2.5 sec/cm.
Sweep output	Front panel 4 mm socket 0 to +8 volt.
HORIZONTAL AMPLIFIER	
Bandwidth	D.C. or 3 Hz to 2 MHz (-3dB) at x1 expansion.
Input Impedance	1 MΩ, 50 pF.
Maximum input voltage	500 volt d.c. or d.c. + a.c. peak.
Sensitivity	1 volt/cm at x1, 200 mV/cm at x5.
X input	Either a.c. or d.c. coupled.
X shift	At least 20 cm.
TRIGGERING FACILITIES	
Selector	Internal channel 1 or 2. External - normal or attenuated 20:1 Supply frequency.
Modes	A.C. (level control operative). D.C. (level control operative). Auto (level control inoperative, timebase free runs).
Slope	The positive or negative switch allows the triggering point to be set on either the positive or negative slope of the triggering waveform.

Trigger requirements	A stable display can be obtained with 2 mm. (internal trigger), 0.15 volt (external trigger). Capable of triggering up to 50 MHz.
Level	Covers the following ranges: ±4 cm on internal trigger. ±3 volt on external trigger. ±60 volt on external attenuated 20:1
Input Impedance	0.5 MΩ, 50 pF.
ENVIRONMENTAL TESTS	Designed to meet REMC/20/FR Cat.3, Issue 4 (General Requirements for Joint Service Electronic and Electrical Test Equipment).
POWER REQUIREMENTS	
A.C. Mains	95 to 130 volt or 190 to 260 volt, 45 to 440 Hz. 45 watts approximately.
External d.c.	24 volt nominal 30 watts approximately.

DIMENSIONS AND WEIGHT

Height	Width	Depth	Weight
254 mm 10 in	254 mm 10 in	356 mm 14 in	11.5 kg. 25 lb.

1.3 ACCESSORIES

SUPPLIED	Mains Lead.	
OPTIONAL	54127-051	Rack Mounting Kit
	54112-011	Carrying Case
	54121-031	Front Panel Protective Cover
	54150-011	Viewing Hood
Probes	TM 8110	Switchable 1:1 or 10:1
	TM 8119	100:1
ALTERNATIVE MODELS	TF 2204/1	Battery Version
	TF 2204/2	N.A.T.O. Version

Chapter 2

Operation

2.1 INTRODUCTION

In order that the TF 2204 18 MHz Oscilloscope may be used most effectively, the operation and capabilities of the instrument must be known. This chapter outlines installation, power supplies, control location and typical basic applications.

The full use of this chapter will probably be necessary only during the initial familiarisation period.

2.2 INSTALLATION

The 18 MHz Oscilloscope is available in four basic versions. The standard version TF 2204 and the Battery version TF 2204/1, have ruggedised NATO equivalents designated the TF 2204/2 and the TF 2204/3 respectively.

All versions have metal feet and a tilt stand fitted on the base for bench use, and plastic feet fitted on the rear for 'face up' use. However, the TF 2204/1 and the TF 2204/3, when fitted with their battery packs (which constitute the base of the instrument) have no tilt facility other than a built-in slight rearward tilt.

2.3 POWER SUPPLIES

All versions may be used with a 95-130 V or 190-260 V 45-440 Hz mains supply.

The TF 2204 and TF 2204/2 may also be used with an external 21-30 V d.c. supply.

The TF 2204/1 and TF 2204/3 are supplied with a rechargeable 24 V d.c. Battery Unit.

Note - For purposes of this Handbook, all references to TF 2204 and TF 2204/1 can be taken to also cover TF 2204/2 and TF 2204/3 respectively - unless otherwise stated.

2.3.1 TF 2204 Power Supply connections (Circuit Diagram Fig. 7.9)

(a) Mains Supply 95-130 V/190-260 V a.c.

The mains lead supplied is fitted with a 3 pin Bulgin socket, which will only fit the rear panel mounted plug marked ~ SUPPLY.

A suitable mains supply plug must be fitted to the other end of the lead by the user.

The three conductors are colour coded according to the International standard as follows:-

LIVE	-	BROWN
NEUTRAL	-	BLUE
EARTH	-	YELLOW/GREEN

Before connecting to the mains supply, check that -

(i) the slide selector switch is in the correct postion (110 V or 220 V).

(ii) the supply fuse FS1 is of the correct rating:-
1 amp for 110 V supply.
500 mA for 220 V supply.

Note - the TF 2204 must not be used with the selector switch set to the incorrect position.

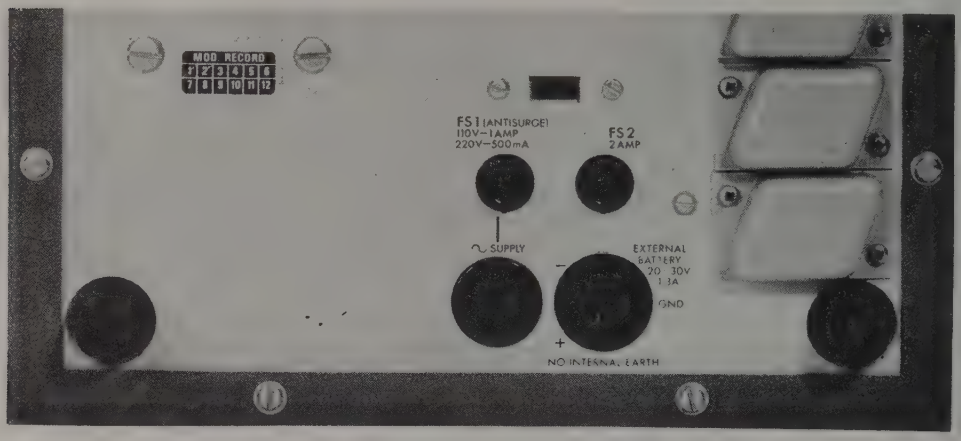


Fig. 2.1(a) TF 2204 Supply controls and connections

(b) External 24 V D.C. Supply.

To convert the TF 2204 for external 24 V d.c. operation proceed as follows -

(i) Ensure instrument is switched off.

(ii) Remove the a.c. mains lead from the ~ SUPPLY plug.

(iii) Connect the d.c. supply via the special D.C. 3 pin Bulgin plug, to the rear panel mounted socket marked EXTERNAL BATTERY. This socket is positioned so that only one of the supply leads can be connected at any one time.

2.3.2 TF 2204/1 Power Supply Connections (Circuit Diagram Fig. 7.10)

(a) Mains Supply 95-130 V/190-260 V a.c.

The information contained in 2.3.1 (a) also applies to the TF 2204/1, except in that the additional switch SR (to the left of the ~ SUPPLY plug) should be in the ~ position.

Note - The mains lead can be fitted simultaneously with the power supply lead from the Battery Unit.

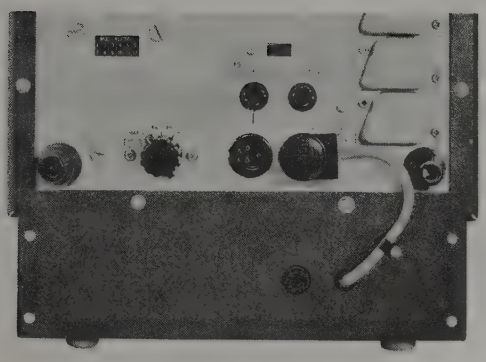


Fig. 2.1 (b) TF 2204/1 Supply Controls and connections

(b) 24 V D.C. Battery Unit operation.

To operate the instrument from the D.C. Battery Unit proceed as follows:-

(i) Ensure instrument is switched off

(ii) Disconnect mains supply lead

(iii) Set switch SR (to the left of the ∿SUPPLY plug) to the BATTERY position.

(iv) Switch on instrument

2.3.3 Using the TF 2204/1 Recharging facility.

To re-charge the batteries proceed as follows:-

(i) Ensure instrument is switched off

(ii) Slide selector switch to relevant position i.e. 110 V or 220 V.

(iii) Check that supply fuse FS1 is of the correct rating i.e. 110 V - 1 A, 220 V - 500 mA

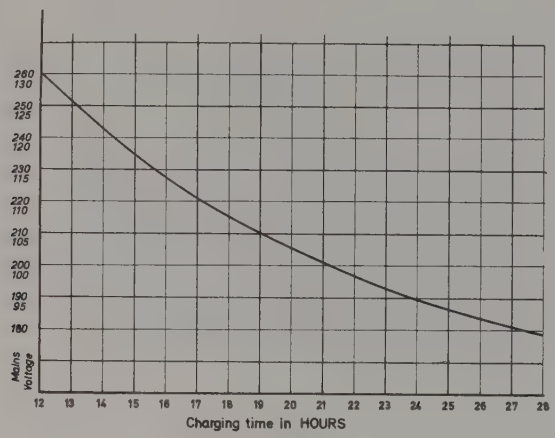
(iv) Connect mains supply lead to ∿ SUPPLY plug

(v) Set switch SR to CHARGE position

(vi) Switch on instrument

It is recommended that the batteries be discharged and then recharged either before permanent use or after a storage period exceeding three months.

The appropriate charging period for a given mains voltage is shown below:-



The batteries will give continous operation for approximately 6 - 8 hours, after being fully charged.

2.4 CONTROLS

The oscilloscope controls can be grouped into four basic sections

(i) C.R.T. and Supply controls

(ii) Vertical Deflection System controls

(iii) Horizontal Deflection System controls

(iv) Trigger controls

2.4.1 C.R.T. and Supply controls

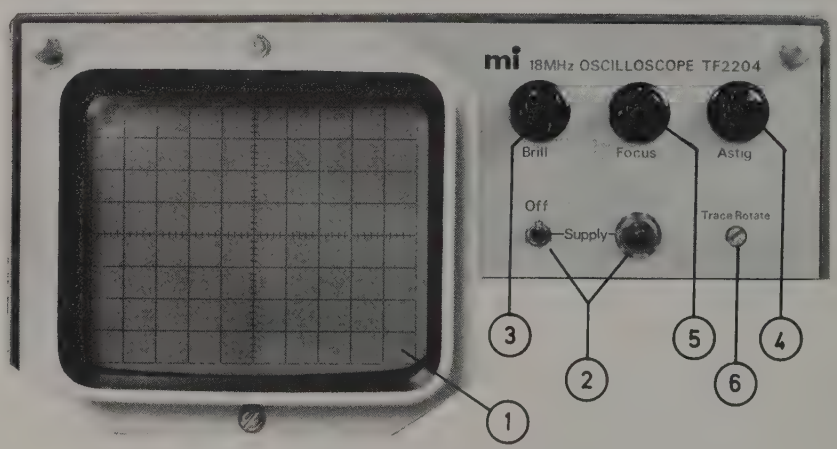


Fig. 2.2 C.R.T and Supply controls

(1) GRATICULE is internally marked on the C.R.T. to enable accurate, parallax free, measurements to be made. It is marked with eight vertical and ten horizontal divisions. Each division is 1 cm square, each major division being divided into five minor divisions at the centre vertical and horizontal graticule lines. The horizontal and vertical deflection systems are calibrated to the graticule for accuracy of measurement.

(2) SUPPLY ON/OFF SWITCH and INDICATOR LAMP. Controls power to the instrument, the lamp illuminating when the instrument is switched on and also when the d.c/a.c. converter is working.

(3) BRILL control increases light intensity of display.

(4) & (5) ASTIG and FOCUS controls used together provide maximum definition of display.

(6) TRACE ROTATE screwdriver control allows limited variation of display horizontal axis, so providing external alignment of tube to graticule.

2.4.2 Vertical Deflection System controls

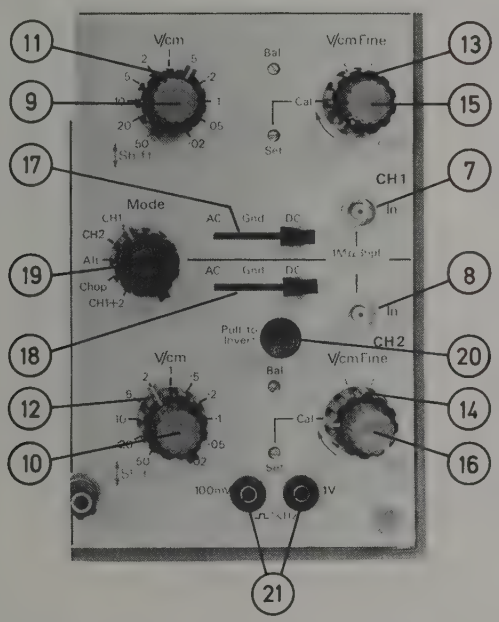


Fig. 2.3 Vertical Deflection System controls

(7) & (8) CH1 IN, CH2 IN (respectively) 50 Ω BNC sockets for input connections of vertical deflection signals (Y axis deflection in the X-Y mode of operation).

(9) & (10) SHIFT control (channel 1 and 2 respectively) for vertical positioning of the display.

(11) & (12) V/CM switched control (channel 1 and 2 respectively) selects the vertical deflection sensitivity in a 1, 2, 5 sequence (for the indicated deflection sensitivity to hold true, the V/cm Fine control must be in the 'CAL' position).

(13) & (14) V/CM FINE control (channel 1 and 2 respectively) provides continously variable deflection sensitivity between the calibrated settings of the V/cm switched control.

(15) & (16) V/CM x1 x10 Gain switch (channel 1 and 2 respectively) when set to x10 position, increases the sensitivity of the pre-amplifier by a factor of 10 (for this to hold true the V/cm Fine control must be in the 'CAL' position).

(17) & (18) AC/GND/DC input coupling switch selects type of input coupling -

- AC Capacitive coupled - Low Frequency limit approximately 10 Hz (-3dB point)
- GND Input circuit grounded (input signal disconnected)
- DC All components of input signal connected.

(19) MODE switch selects vertical mode of operation -

- CH1 Signal connected to CH1 input socket displayed.
- CH2 Signal connected to CH2 input socket displayed.
- ALT Dual-trace display of CH1 and CH2 signals. Channel switching occurs at the selected sweep frequency.
- CHOP Dual-trace display of CH1 and CH2 signals. Channel switching occurs at approximately 400 Hz.
- CH1 + 2 Algebraic sum of the CH1 and CH2 signals displayed on C.R.T (see Pull to Invert).

(20) PULL TO INVERT switch changes the CH1 + 2 mode to CH1 − 2.

(21) 100 mV - 1 kHz and 1 V - 1 kHz calibrator output sockets.

2.4.3 Horizontal Deflection System controls

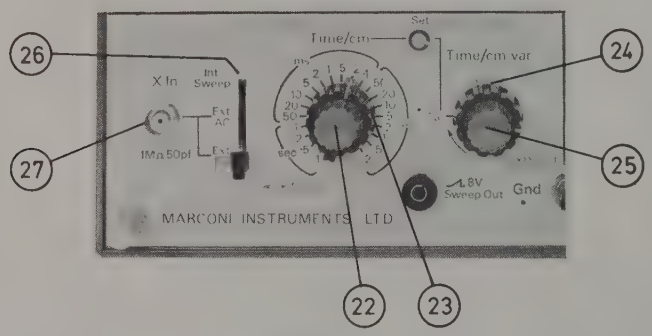


Fig. 2.4 Horizontal Deflection System controls

(22) SHIFT control for horizontal positioning of the display.

(23) TIME/CM switch control selects the horizontal sweep rate in a 1, 2, 5 sequence (Time/cm Var must be in the 'CAL' position for the indicated sweep rate to hold true).

(24) TIME/CM VAR control provides continously variable sweep rate between the calibrated settings of the Time/cm switch.

(25) TIME/CM x1 x5 Expand switch when set to x5, increases the sweep rate by a factor of 5 (for this to hold true the Time/cm var must be in the 'CAL' position).

(26) INT SWEEP/EXT AC/EXT DC input coupling switch selects input to the output X-amplifier -

INT SWEEP	Horizontal deflection provided by internal timebase.
EXT AC	External sweep, capacitive coupled - low frequency limit approximately 10 Hz (-3dB point).
EXT DC	External sweep, all components of sweep waveform fed to output X-amplifier.

(27) X IN 50 Ω BNC socket for input connections of external horizontal sweep (X-axis deflection in the X-Y mode of operation).

2.4.4 Trigger Controls

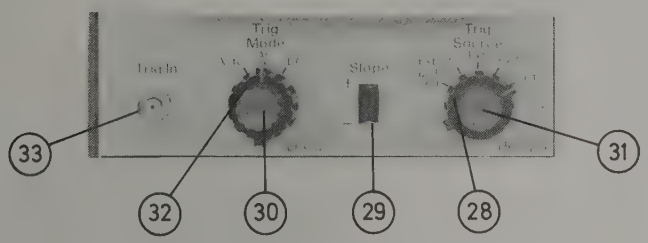


Fig. 2.5 Trigger Controls

(28) TRIG SOURCE switch selects source of triggering signal from horizontal sweep -

CH1	Sweep triggered from signal applied to 'CH1 In'
CH2	Sweep triggered from signal applied to 'CH2 In'
EXT	Sweep triggered from signal applied to 'Trig In'
EXT ÷ 20	External trigger at 'Trig In' attenuated by a factor of 20.

(29) SLOPE switch selects slope of trigger signal that initiates the sweep -

+	Sweep triggered from positive-going edge of trigger signal.
−	Sweep triggered from negative-going edge of trigger signal.

(30) LEVEL control permits the sweep to be initiated on the selected portion of the trigger signal.

(31) HF SYNC control permits stable triggering to be obtained at high sweep repetition rates (greater than 5 MHz). Has negligible effect at lower repetition rates.

(32) TRIG MODE switch selects trigger signal coupling -

AUTO	Level control inoperative. Trigger occurs on the mean level of the trigger signal. In the absence of a trigger signal the timebase free runs at a slow rate.
AC	Accepts trigger signals from approximately 10 Hz to > 15 MHz.
DC	Accepts trigger signals from d.c. to > 15 MHz approximately.

(33) TRIG IN 50 Ω BNC input socket for external trigger signals.

2.5 PREPARATIONS FOR USE

It is recommended that the following procedure be followed completely for a first-time familiarisation with the instrument. It is assumed that the appropriate line voltage settings have been made as in Chapter 2.2.

2.5.1 Familiarisation Procedure

(a) Set the front-panel controls as follows:-

(i) C.R.T. controls

BRILL	Counter-clockwise
FOCUS	Mid-Position
ASTIG	Mid-Position

(ii) Vertical deflection system controls. (both channels if applicable).

V/cm	2
SHIFT	Mid-position
V/cm FINE	CAL
V/cm x1, x10, GAIN	x1
Input coupling	DC
MODE	ALT
PULL TO INVERT	Pushed in

(iii) Horizontal deflection system controls

TIME/cm	.5 ms
TIME/cm VAR	CAL
TIME/cm x1, x5 EXPAND	x1
Input coupling	INT SWEEP

(iv) Trigger

TRIG SOURCE	CH1
LEVEL	Mid-position
SLOPE	+
TRIG MODE	AUTO
HF SYNC	Mid-position

(b) Connect the TF 2204 to a power supply that meets the voltage and frequency requirements of the instrument. See chapter 2.3.

(c) Set the SUPPLY switch downwards (on). Check that the SUPPLY panel lamp lights. Allow several minutes to elapse so that the instrument can reach its operating temperature before proceeding to (d).

(d) Connect the 1 V, 1 kHz calibration output to CH1 IN.

(e) Advance the BRILL control until the intensity of the trace is adequate. Slight adjustment of the CH1 and CH2 SHIFT controls may be required to position the traces on the screen.

NOTE: To increase the life of the c.r.t. do not turn the BRILL control higher than necessary for a satisfactory display.

(f) Adjust the FOCUS and ASTIG controls to obtain a well-defined trace.

NOTE: To check for proper setting of the ASTIG control, slowly turn the FOCUS control through the optimum setting. If the ASTIG adjustment is correctly set, the horizontal and vertical portions of the CH1 trace will come into sharpest focus at one position of the focus control. The setting of the ASTIG control should then be correct for any display.

(g) Adjust the CH2 SHIFT control to position the CH2 trace coincident with the centre horizontal graticule line. (if the trace is not parallel with this line, refer to chapter 4.3.3 for trace alignment adjustment). Offset the CH2 trace from the C.R.T. screen.

(h) Note that the vertical deflection (CH1) of the displayed calibration waveform is exactly five dimensions (1 V, i.e. 5 cm x 0.2 V/cm). (if not, refer to Chapter 4.3.5, for front-panel vertical gain adjustment).

(j) Rotate the V/cm FINE control fully counter-clockwise from CAL. Note that the vetical deflection sensitivity is reduced by a factor of at least 2.5. Return the control to CAL.

(k) Note that the period of the displayed waveform is exactly 2 cm (1 ms, i.e. 2 cm x 0.5 ms/cm). (It not refer to chapter 4.3.11 for front-panel horizontal gain adjustment).

(m) Set the TIME/cm x1, x5 EXPAND switch to x5. Note that the sweep rate is increased by a factor of 5. Return the switch to the x1 position.

(n) Rotate the TIME/cm VAR control fully counter-clockwise from CAL. Note that the sweep rate is decreased by a factor of at least 2.5. Return the control to CAL.

(p) Set the trigger SLOPE switch to −. Note that the trace starts on the negative-going portion of the square wave. Return the switch to +; note that the trace now starts on the positive going portion of the square wave.

This completes the basic familiarisation procedure. Detailed information is given under General Operating Information, Chapter 2.6.

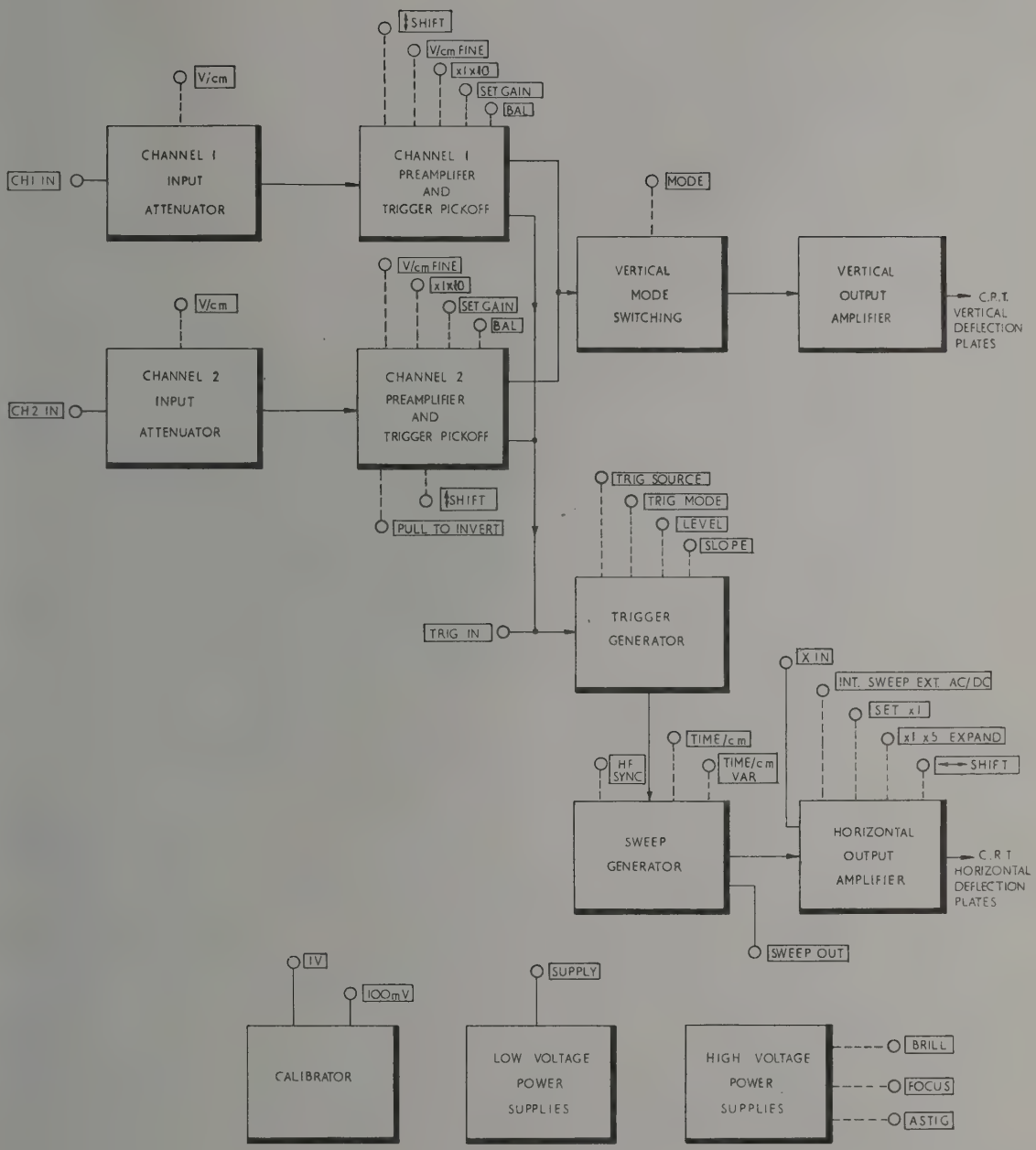


Fig. 2.6 18 MHz Oscilloscope
Overall Block Diagram

2.6 GENERAL OPERATING INFORMATION

2.6.1 Introduction

The TF 2204 consists, basically, of a dual-channel vertical deflection system, a trigger generator, a horizontal deflection system, a calibrator and high and low-voltage supplies. Fig. 2.6 shows an overall block diagram of the instrument illustrating the main functional units and front-panel controls. An appreciation of the location of these controls in relation to the various functional units is especially helpful if full use of the instrument and its applications is to be made. Cross-reference to the block diagram and to the description of the function of the front-panel controls is recommended, therefore, whenever reference is made to the General Operating Information and Basic Application sections.

To increase c.r.t. life, avoid advancing the BRILL control beyond a setting that provides a satisfactory display. In addition, ensure that the BRILL control is not set too high when the TIME/cm switch is changed from a fast to a slow sweep rate.

The focus of the display may be affected when the BRILL control is adjusted. Slight readjustment of the FOCUS control may thus be required whenever the brilliance level is changed.

2.6.2 Signal Input Coupling

The type of display required determines the mode of input coupling. D.C. coupling can be used for most applications especially if the frequency of the a.c. component is below 10 Hz; in the AC position, attenuation of a.c. components below 10 Hz occurs. However, if the signal contains a large d.c. component, the AC position will produce a better display. Because of the 10 Hz (-3dB point) frequency limit, some low-frequency distortion will occur; this will be apparent in pulse waveforms that have low-frequency components.

In the GND position, the input signal is internally disconnected and the amplifier input is grounded. This facility provides a ground reference without having to externally ground the input.

2.6.3 Trigger

(a) Trigger Source

(i) CH1 and CH2. The time base can be triggered from the signal input for most applications. In the CH1 and CH2 positions of the TRIG SOURCE switch, the trigger signal is derived from the signal applied to the relevant channel of the vertical deflection system. For dual-trace operation, special triggering conditions may be required (Refer to Chapter 2.6.5).

(ii) EXT and EXT ÷20. The timebase can be triggered from an external input connected to TRIG IN the TRIG SOURCE switch being set to either of these positions. However, for a stable display, the trigger signal must be time-related to the displayed signal. Typical uses of the external trigger facility are when the internal trigger is too low in amplitude for stable triggering, when the internal trigger contains components on which triggering is not desirable, or when time relationships with respect to a certain time have to be examined. In the latter case, a typical external trigger waveform could be a pre-pulse or clock pulse. High amplitude trigger signals can be attenuated by 20:1 (EXT ÷ 20 position) to broaden the range of the LEVEL control.

(iii) SUPPLY FREQ. In this position of the TRIG SOURCE switch; a portion of the supply line voltage is used as an internal trigger. Typical uses of this facility are when the displayed signal is related in time (multiple or sub-multiple) to the line frequency or when a stable display of a line-frequency component in a complex waveform is required.

(b) Trigger Mode

(i) AUTO. In this position of the TRIG MODE switch, the LEVEL control is inoperative and the trigger instant occurs on the mean level of the trigger waveform. In the absence of a trigger, the timebase free runs at a rate dependent on the selected sweep rate.

(ii) AC and DC. The a.c. trigger mode can be used for most applications except for trigger signals of low P.R.F. or low frequency: attenuation of a.c. components below 10 Hz occurs in this mode and thus the d.c. mode should be used for these types of trigger signals. The d.c. mode should not be used for a trigger signal that has a large d.c. component.

(c) Trigger Slope Level (Fig. 2.7) The SLOPE switch determines the slope (+ : positive-going, —: negative - going) of the trigger signal on which the trigger circuit responds. If several periods of a signal are to be displayed, the setting of the SLOPE switch is not necessarily important. However if only a portion of a signal is to be displayed, the SLOPE switch must be correctly set to provide the desired display.

The LEVEL control permits the sweep to be initiated on the selection of the trigger signal. Clockwise rotation of the control causes the trigger circuit to respond at a more positive point on the trigger signal; counter-clockwise rotation causes the trigger circuit to respond at a more negative point. The control should be adjusted once the TRIG SOURCE, SLOPE and TRIG MODE switches have been set.

(d) High-frequency Stability If a sweep trigger occurs near the instant the sweep hold-off period ends (e.g. at triggering frequencies of 5 MHz or more), then the hold-off period can be adjusted with the HF SYNC control to obtain a stable display.

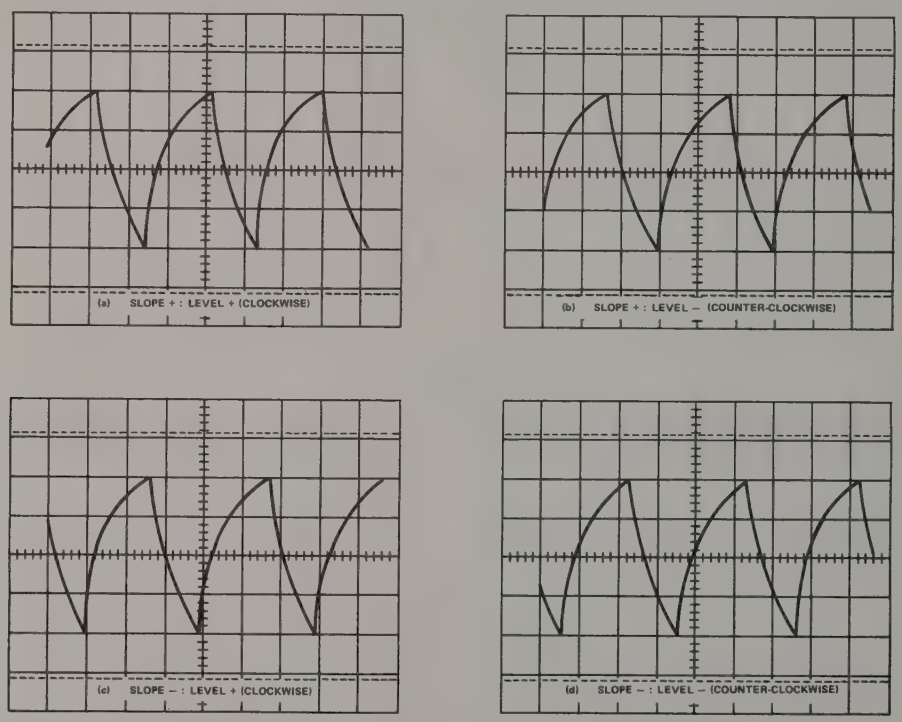


Fig. 2.7. Effect of Trigger Slope and Level on the Trigger Point

2.6.4 Sweep Mode

(a) Internal sweep.
In the INT SWEEP mode, the sweep rate is controlled by the TIME/cm and x1, x5 EXPAND switches, the TIME/cm VAR control being set to the CAL position. When EXPAND switch is set to x5, the sweep rate is determined by dividing the TIME/cm switch setting by 5. For example, if the switch is set to 50 μs, the magnified sweep rate is 10 μs/cm. The desired number of cycles of a displayed waveform can be set by the TIME/cm VAR control, which provides a continuously-variable sweep rate between the calibrated settings of the TIME/cm switch.

(b) External sweep. In the EXT DC or EXT AC modes, the sweep is determined by a signal applied to the X IN connection. The choice of a.c. or d.c. coupling is dependent upon the content of the input waveform: d.c. coupling is suitable for most inputs, especially if the frequency of the a.c. component is below 10 Hz - in the EXT AC mode attenuation of components below 10 Hz occurs. However, if the signal contains a large d.c. component, the EXT AC mode should be used, otherwise the d.c. offset in the X-deflection will be beyond the range of the SHIFT control (see 2.6.4 (c)). The sensitivity of the sweep on external inputs is 1 V/cm approximately, when the EXPAND switch is set x1. For large amplitude inputs therefore, only the first 16 V approximately will form the effective sweep, the horizontal SHIFT control being adjusted as necessary.

(c) Horizontal position. The horizontal position of the sweep can be set by the SHIFT control, which provides at least 20 cm of control, i.e. the trace can be shifted off the screen in either direction.

2.6.5 Vertical Deflection Modes

(a) CH1 mode. In the CH1 position of the MODE switch, the display is single beam and CH1 signals only are displayed. If the trigger mode selected is CH2 or EXT, a stable display will only be obtained if the channel 2 or external triggering signal is time related to the channel 1 signal.

(b) CH2 mode. In the CH2 position of the MODE switch, the display is single beam and CH2 signals only are displayed. If the trigger mode selected is CH1 or EXT, a stable display will only be obtained if the channel 1 or external triggering signal is time related to the channel 2 signal.

(c) Alternate mode. The ALT position of the MODE switch produces a display which alternates between channel 1 and channel 2 with each timebase sweep, the sweep being triggered as selected by the TRIG MODE switch. The signals on both channels, if time-related, are displayed showing true time relationship. However, if the signals are not time-related, then the waveform not time related to the selected triggering signal will appear unstable. The ALT mode can be used at all sweep rates, but at sweep rates below about 20 ms/cm, alternate mode switching becomes visually perceptible.

(d) Chopped mode. The CHOP position of the MODE switch produces a display which is switched at approximately 400 kHz, between the two channels. The CHOP mode provides a more satisfactory display than the ALT mode at sweep rates slower than about 20 ms/cm or whenever a dual-trace single-shot event is to be displayed. At sweep rates faster than 20 ms/cm, due to only chopped 2 μs portions of the signals being displayed, the chopped switching becomes perceptible and may interfere with the display. The signals on each channel, if time related, are displayed showing true time relationship. However, if the signals are not time related, then the waveform not time related to the selected triggering signal will appear unstable.

(e) CH1 & 2 mode. The CH1 + 2 position of the MODE switch can be used:-

(i) to display the sum or difference of two signals.

(ii) to remove an unwanted signal by common mode rejection.

The PULL TO INVERT switch in channel 2 can be used to facilitate these uses. The overall deflection sensitivity in the CH1 + 2 mode when both V/cm switches are set to the same position is the same as the deflection sensitivity indicated by either switch. This also provides a similar response from each channel. However, if the CH1 and CH2 V/cm switches are set to different deflection sensitivities (e.g. in common-mode rejection), the resultant waveform amplitude can only be determined accurately if the amplitude of the signal applied to either channel is known. To ensure the optimum deflection range for this mode, the CH1 and CH2 SHIFT controls should be set to position the signal on each channel to mid-screen, the MODE switch being set to CH1, then CH2 respectively.

NOTE: The rejection ratio can be set to any value by applying the same signal to both inputs simultaneously, and then adjusting one or both fine gain controls to minimise the deflection.

2.6.6 X-Y Operation

To display two signals against each other rather than against time, a signal applied to X IN provides a method of applying an external signal to the X-amplifier, the sweep mode switch being set to EXT AC or EXT DC as required. The vertical deflection is obtained by applying a signal to either CH1 IN or CH2 IN. The horizontal SHIFT control provides X-axis position and the appropriate vertical SHIFT control provides Y-axis position.

The type of display required determines the mode of input coupling used. The EXT DC coupling can be used for most applications but if the d.c. component of the signal is much larger than the a.c. component, EXT AC coupling should be used. EXT DC coupling should be used to display a.c. signals below about 10 Hz as attenuation of these signals, due to the blocking capacitor in the input circuit, occurs in the EXT AC position.

The X-Y type of display can be used to measure the phase difference between two signals of the same frequency, if this frequency is below approximately 70 kHz. Above this frequency, the effect of the 180 ns delay line in the vertical deflection channel causes the measurement to become inaccurate.

2.6.7 Calibrator

The calibrator provides a convenient voltage source for checking the performance of the horizontal and vertical deflection systems. For maximum accuracy, however, the adjustment procedures detailed in Chapter 4.3 should be used for recalibration.

The calibrator can also be used as a signal source for external equipment and provides accurate, 100 mV and 1 V peak-to-peak square-wave outputs into a high impedance load at a frequency of 1 kHz. The output impedance of the calibrator is approximately 250 Ω.

2.7 TYPICAL BASIC APPLICATIONS

These applications are for guidance only and each must be adapted to a specific measurement

2.7.1 Voltage Measurement

(a) AC Measurement (Fig. 2.8) This procedure can be used to measure the peak-to-peak amplitude of a waveform or between two points (in amplitude) on the waveform.

(i) Connect the signal to CH1 IN and set the input coupling to AC.

NOTE: If the frequency of the signal is below about 10 Hz. set the input coupling to DC.

(ii) Set vertical MODE to CH1, CH1 V/cm FINE to CAL, and CH1 V/cm for a deflection of approximately 6 cm.

(iii) Adjust the trigger controls to obtain a stable display and set TIME/cm so that several cycles are displayed.

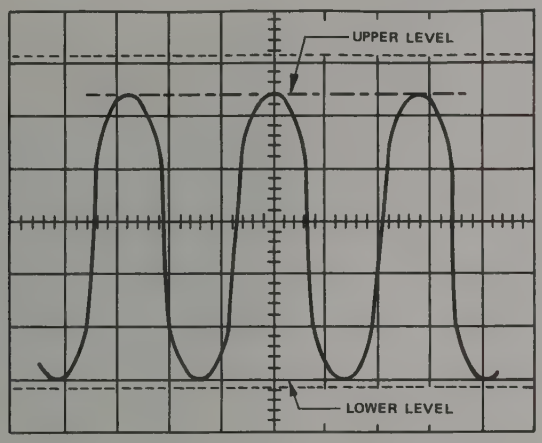


Fig. 2.8. Measurement of AC Voltages

(iv) Adjust CH1 SHIFT to position the lower point to be measured on a horizontal graticule line on the lower half of the screen.

(v) Adjust ↔ SHIFT to position the upper point to be measured on the centre vertical graticule line.

(vi) Note the required amplitude (in cm): to obtain the amplitude in volts, multiply this by the V/cm setting, and the attenuation factor of any probe used.

Example

In Fig. 2.8. the peak-to-peak amplitude of the indicated waveform is 5.4 cm. If the V/cm, setting is 5 V/cm, then the waveform amplitude is 27 volts.

(b) DC Measurement (Fig. 2.9)

This procedure may be used to measure an instantaneous d.c. voltage or a d.c. level with respect to ground or with respect to a voltage other than ground.

(i) Connect the signal to CH1 IN and set vertical channel MODE to CH1, CH1 V/cm FINE to CAL, and V/cm for a deflection of approximately 6 cm.

(ii) Set the CH1 input coupling to GND and select AUTO trigger.

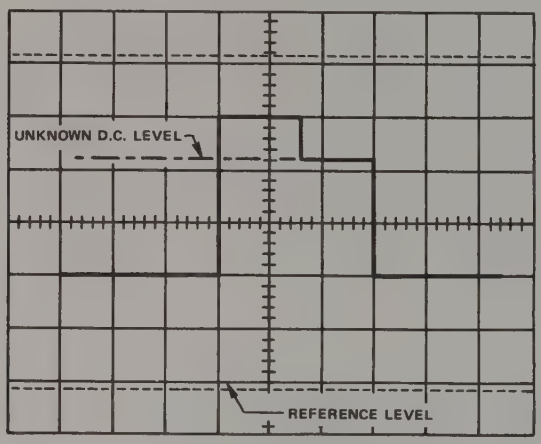


Fig. 2.9. Measurement of DC Voltages

(iii) If the voltage to be measured is positive with respect to ground, adjust CH1 SHIFT to position the trace on the bottom horizontal graticule line or other reference line. If the voltage is negative with respect to ground, position the trace on the top horizontal graticule line.

NOTE: To measure with respect to a voltage other than ground, disconnect the signal from CH1 IN, set input coupling to DC and apply the reference voltage to CH1 IN. Position the trace to a reference horizontal graticule line. Disconnect the reference voltage and reconnect the signal.

(iv) SET CH1 input coupling to DC. Select CH1 trigger and adjust TIME/cm and trigger controls for a stable display of several cycles.

(v) Note the distance in centimetres between the reference line and the required point on the signal, and note the polarity. To obtain the amplitude in volts, multiply the distance by the V/cm setting and the attenuation factor of any probe used.

Example

In Fig. 2.9. the distance between the reference level and the required level on the indicated waveform is 4.2 cm (positive). If the V/cm setting is 2 V/cm, then the required level is 8.4 V positive with respect to the reference voltage.

(c) Comparison of Voltages. Where it is necessary to compare the amplitude of a signal with that of an a.c. reference signal, a deflection sensitivity, different from those indicated on the V/cm switch, may be required. The following procedure can be used to obtain the relevant sensitivity.

(i) Connect the reference signal of known amplitude to CH1 IN, and select CH1 vertical MODE and CH1 TRIG MODE.

(ii) Adjust V/cm and V/cm FINE for an exact number of centimetres of vertical deflection. Maintain this V/cm FINE setting. If necessary, adjust the trigger controls for a stable display.

(iii) Calculate the vertical conversion coefficient (V.C.C.) where

$$\text{V.C.C.} = \frac{\text{Amplitude of reference voltage (volts)}}{\text{V/cm setting x deflection (cm)}}$$

(iv) Calculate the effective deflection sensitivity (E.D.S.) where

$$\text{E.D.S} = \text{V/cm setting x V.C.C.}$$

(v) Disconnect the reference signal and connect the input signal.

(vi) If necessary, reset V/cm only, for an adequate deflection and re-adjust the trigger controls for a stable display.

(vii) Note the vertical deflection. To calculate the signal amplitude in volts:-

$$\text{Signal amplitude} = \text{E.D.S. x deflection (cm)}$$

2.7.2 Time Measurement

(a) Time Duration (Fig. 2.10)

(i) Connect the Signal to CH1 IN and set TRIG MODE and vertical MODE to CH1.

(ii) Set TIME/cm VAR to CAL and adjust TIME/cm so that the maximum distance between the points to be measured is approximately eight cm.

(iii) Adjust CH1 SHIFT to position the points on the centre horizontal graticule line, if convenient to do so.

(iv) Adjust ↔ SHIFT to position one point on the intersection of a vertical and the horizontal graticule lines.

(v) Note the distance (in cm) between the points. Multiply this by the TIME/cm setting (and divide by 5 if the x5 EXPAND setting is used) to obtain the required time interval.

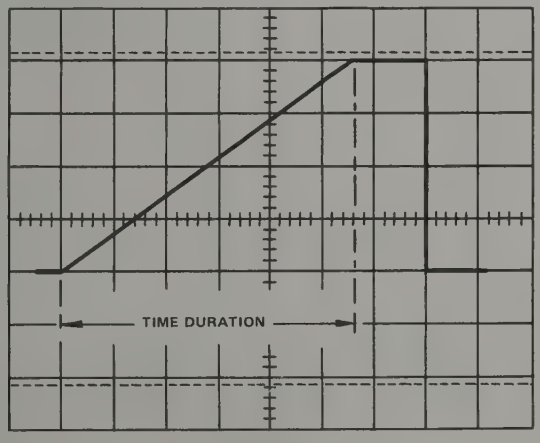


Fig. 2.10. Measurement of Time Duration

Example

In Fig. 2.10, the distance between the two points is 5.6 cm. If the TIME/cm setting is 20 μs/cm and x5 EXPAND is selected, the time interval is 22.4 μs.

(b) Frequency Measurement. The frequency of a periodically-recurrent signal is the reciprocal of the time duration of one cycle.

(i) Measure the time duration of one cycle (chapter 2.7.2 (a)).

(ii) Take the reciprocal to determine the frequency.

(c) Rise Time (Fig. 2.11). Measurement of rise-time is similar to the procedure detailed in Chapter 2.7.2, the interval being between the 10% and 90% points on the leading edge of the waveform. Fall-time is measured on the trailing edge of the waveform.

(i) Connect the signal to CH1 IN and set TRIG MODE and vertical MODE to CH1.

(ii) Set V/cm and V/cm FINE so that the vertical deflection is an exact number of centimetres: this allows for an accurate estimation of the 10% and 90% points. If necessary, adjust SLOPE and trigger controls so that all of the leading edge is displayed.

(iii) Set TIME/cm FINE to CAL and adjust TIME/cm so that the maximum duration of the rise-time is approximately eight cm.

(iv) Determine the 10% and 90% points. Adjust ↔ SHIFT so that the 10% point lies on a vertical graticule line.

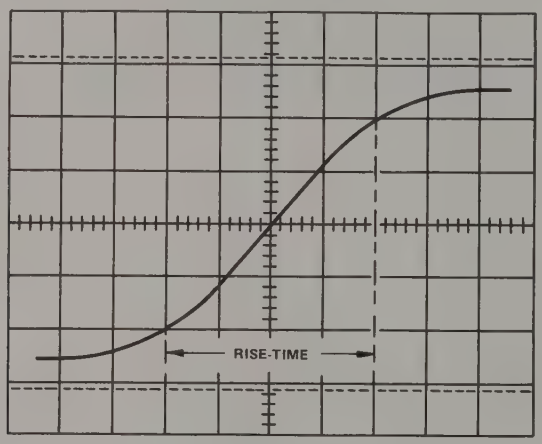


Fig. 2.11 Measurement of Rise Time

(v) Note the horizontal distance (in cm) between the 10% and 90% points. Multiply this by the TIME/cm setting (and divide by 5 if the x5 EXPAND setting is used) to obtain the rise- time.

Example

In Fig. 2.11 the distance between the 10% and 90% pointsis 4.2 cm. If the TIME/cm setting is 0.5 μs/cm, the rise-time is 2.1 μs.

(d) Time Difference (Dual-trace Operation) (Fig. 2.12). The dual-trace facility allows the time difference between two separate time-related events to be measured. The sweep must be triggered from the signal which occurs first (e.g. a system trigger) and, if possible, co-axial cables of equal length should be used to connect the signals to the two vertical channels, thus minimising any delay errors.

(i) Set vertical MODE to CHOP or ALT, and CH1 and CH2 input coupling as required (Chapter 2.6.5).

(ii) Set TRIG MODE to CH1. Connect the reference signal to CH1 IN and the comparison signal to CH2 IN.

(iii) Adjust CH1 and CH2 V/cm for display amplitudes of 5 cm to 6 cm, and adjust the trigger controls for a stable display.

(iv) Set TIME/cm FINE to CAL and adjust TIME/cm so that the interval between the two points can be measured.

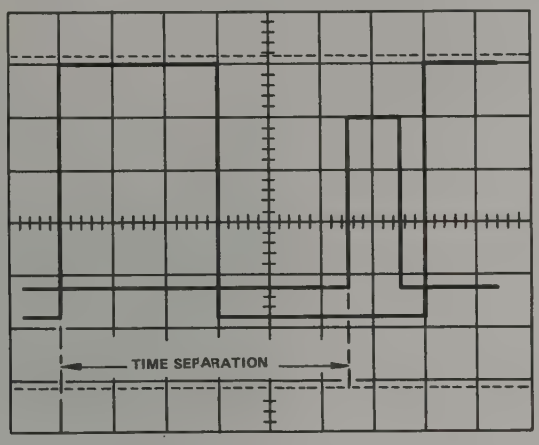


Fig. 2.12 Measurement of Time Difference (Dual Trace Operation)

(v) Adjust CH1 and CH2 SHIFT so that the points to be measured lie on the centre horizontal graticule line. Adjust ↔ SHIFT so that one point lies on the intersection of the horizontal and a vertical graticule line.

(vi) Note the horizontal distance (in cm) between the two points. Multiply this by the TIME/cm setting (and divide by 5 if the x5 EXPAND setting is used) to obtain the time difference.

Example

In Fig. 2.12 the distance between the two points is 5.5 cm. If the TIME/cm setting is 2 μs/cm, the time difference is 11 μs.

(e) Phase Difference—Dual Trace Operation (Fig. 2.13). If the phase difference between two time-related signals of the same frequency is required, the dual-trace application of measuring time difference (Chapter 2.7.2(d)) can be used.

(i) Proceed as in the time-difference application (Chapter 2.7.2(d)-(i) to (v)) but adjust TIME/cm and TIME/cm FINE so that the CH1 signal occupies exactly eight centimetres. Each of these eight centimetres represents 45 deg of the cycle, i.e. the effective sweep rate is 45 deg/cm.

NOTE: If the signals are of opposite phase, PULL TO INVERT CH2, and take this 180 degree change on CH2 into account when calculating the phase difference in (ii).

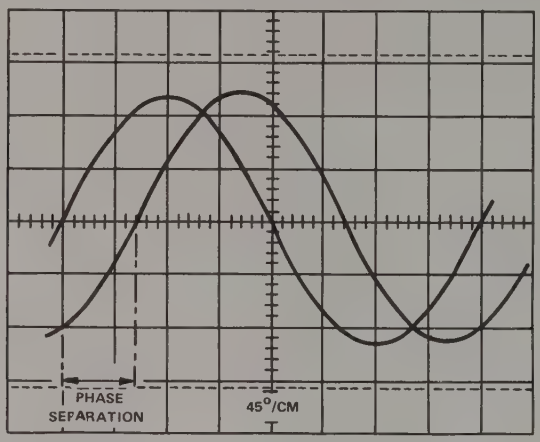


Fig. 2.13 Measurement of Phase Difference (Dual Trace Operation)

(ii) Note the horizontal difference (in cm) between equivalent points on the two signals. Multiply this by 45 deg/cm to obtain the phase difference.

NOTE: A more accurate measurement can be obtained by switching to x5 EXPAND facility once the cycle duration of eight centimetres is set. The effective sweep rate is then 9 deg/cm.

Example

In Fig. 2.13 the distance due to phase between the two signals is 1.4 cm. Thus the phase difference is 63 deg.

(f) X-Y Operation (Figs. 2.14, 2.15). If the phase difference between two time-related signals of the same frequency is required, the following method can be used, up to the frequency limit of 70 kHz (last paragraph Chapter 2.6.6).

(i) Connect one signal to CH1 IN, the other to X IN.

(ii) Set CH1 and X input coupling to AC and EXT AC, respectively.

NOTE: If the signal frequency is below approximately 10 Hz, select DC and EXT DC coupling.

(iii) Adjust CH1 V/cm for a vertical deflection of approximately 6 cm, and adjust the amplitude of the X input signal for a horizontal deflection of approximately 8 cm. (set TIME/cm EXPAND to x1 or x5, as convenient).

(iv) Centralise the display about the centre horizontal graticule line. With reference to Fig. 2.13 note the two distances a and b. Then the sine of the phase angle, ϕ, between the two signals is given by a/b.

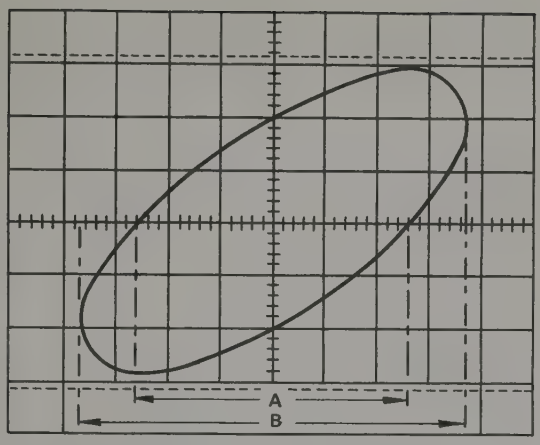


Fig. 2.14 Measurement of Phase Difference (X-Y Operation)

Example

In Fig. 2.14 $\underline{a}$ is 5.2 cm and $\underline{b}$ is 7.4 cm.

$$a/b = 0.704$$
$$= \sin \phi$$

$\therefore \phi \triangleq 45$ deg.

NOTE: Fig. 2.15 shows several lissajous figures resulting from waveforms that have phase differences between 0 deg and 360 deg. Above 180 deg phase difference, it will be noticed that the lissajous figure for a particular phase angle is the same as that of some lower phase angle. Care should be taken, therefore, to obtain the correct phase angle from measurement.

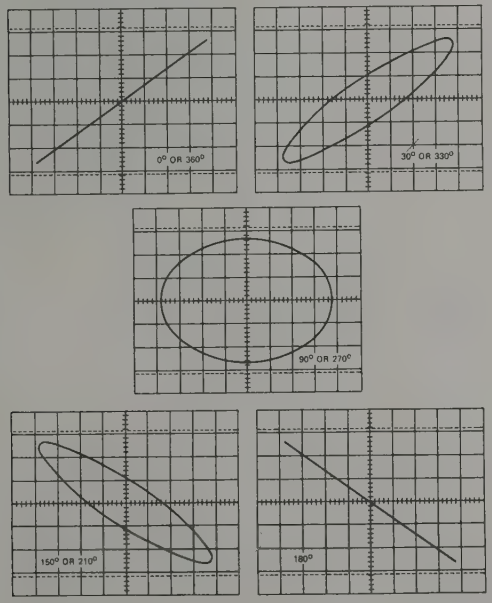


Fig. 2.15 Typical Lissajous Figures

2.7.3 Common Mode Rejection

This procedure details a method of removing a line-frequency or similar component from a displayed waveform. The method for displaying the sum or difference of two signals, (see 2.6.5 (e)) is similar.

(i) Connect the signal containing the unwanted component to CH1 IN. Set TRIG MODE to CH1, vertical MODE to ALT, input coupling to DC (AC if a large d.c. component is present).

(ii) Adjust CH1 V/cm for a deflection of approximately 5 cm and the trigger controls for a stable display.

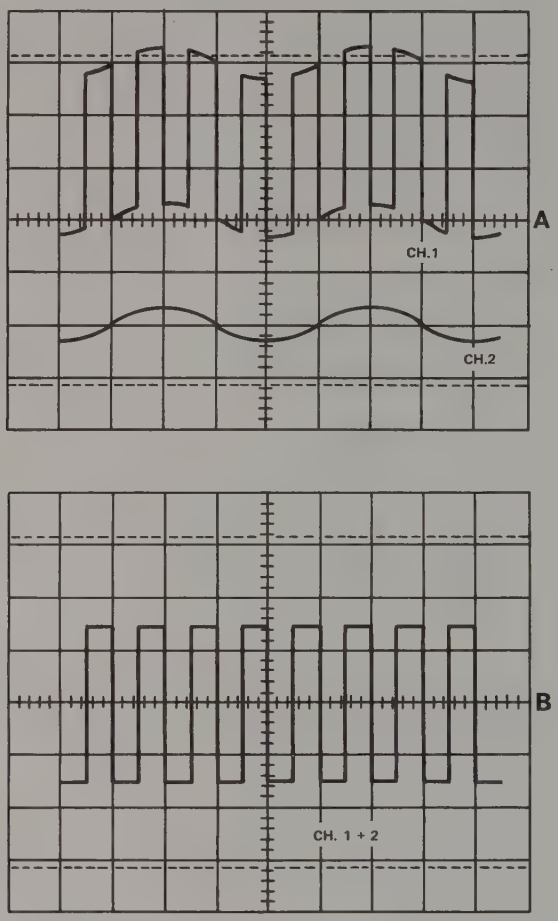


Fig. 2.16 Effect of Common Mode Rejection

(iii) Connect a signal similar to the unwanted component of the CH1 signal to CH2 IN, input coupling to DC. Adjust CH2 V/cm for a deflection about equal to that of the unwanted signal apparent on the CH1 display.

(iv) Set vertical MODE to CH1 + 2 and PULL TO INVERT CH2.

(v) Adjust CH2 V/cm and V/cm FINE for maximum cancellation of the unwanted signal.

Example

Fig. 2.16(a) shows the two signals displayed in the ALT vertical mode, and Fig. 2.16 (b) shows the resultant cancellation in the CH1 + 2, PULL TO INVERT vertical mode.

Chapter 3

Technical description

3.1 INTRODUCTION

The TF 2204 contains six wired-in sub units, which are coded as follows:-

	Code
Power unit	X1
Trigger, sweep generator and X amplifier	X2
Y-Amplifier	X3
Vertical output amplifier	X4
CH1 attenuator	X5
CH2 attenuator	X6

Throughout this manual any component mounted on one of these units is identified, for clarity, by an appropriate code-number prefix (based on the component reference) followed by the circuit reference number. For example, 3D13 refers to D13 in the Y-amplifier X3. Components with no prefix are mounted on the main assembly. The code prefixes do not appear on the silk-screening of the units.

3.2 SYSTEMS OPERATION

Fig 2.6 shows an overall block diagram of the instrument and illustrates the inter-relation of the main functional units and front-panel controls. The following description is written mainly around Fig 7.1, Block Schematic, which illustrates the inter-relation of the various systems that form the oscilloscope.

3.2.1 Vertical Deflection System

(a) The two signal channels are similar and the outputs of each channel are switched, dependent upon the vertical mode selected via a delay line and a vertical output amplifier to the c.r.t. Y plates. Signal channel 1 only is described in (b) to (d); differences relating to signal channel 2 are described in (e); vertical mode switching, the delay line and the vertical output stage are described in (f) to (i).

(b) The input signal to CH1 is connected to CH1 IN (SKT F) and thence, via input coupling switch (SN), to switched attenuator V/cm (5SA) which provides eleven attenuation ratios (from 1:1 to 2500:1). This attenuator presents constant input impedance and input capacity on all eleven ranges. From the attenuator, the signal is fed to an impedance changer, 3VT1 and 3VT2, the main component being a field-effect transistor. Any d.c. shift in the c.r.t. display, between short-circuit and open-circuit input conditions, is minimised in this stage by a preset control.

(c) The pre-amplifier comprises a long-tailed pair with a constant-current source, and part of a balanced cascode amplifier. In addition, a trigger pickoff circuit, comprising a balanced amplifier and an output amplifier, applies a sample of the input waveform to the trigger source switch (SC). A selected portion of this waveform sample can then be used to trigger the sweep in the sweep generator. The remaining part of the cascode output amplifier is common to both signal channels, forms part of the vertical output amplifier, and is switched into circuit dependent upon the vertical deflection mode selected.

(d) Several front-panel controls are associated with the pre-amplifier (see Fig 2.6) of which SET GAIN and BALance are pre-set controls. Other, internal, controls allow the x10 gain and coarse balance to be preset: adjustment for frequency compensation is also provided.

(e) Signal channel 2 is similar to channel 1, but an additional front-panel control (PULL TO INVERT) is incorporated in the cascode amplifier. This control, a change-over switch, changes the sense of the output from the first part of the cascode amplifier thus providing an effective signal inversion when required.

(f) The signal applied via the delay line to the common part of the cascode amplifier can be:

(i) from one of the signal channels (CH1 or CH2 modes).

(ii) switched alternately from each channel (ALT or CHOP modes).

(iii) composite, from both channels (CH1 + 2 mode).

(g) In modes other than the CHOP mode, the vertical mode oscillator (3VT29, 3VT30 and 3VT32) is inoperative, while in modes other than the ALT mode, the alternate-mode trigger shaper (2VT10) is inoperative. In all modes, the biasing level of the vertical mode bistable (3VT27, 3VT38) is determined by the MODE switch, as follows:-

(i) CH1. Biased such that a grating input is fed to the two switched linear gates 3D3, 3D4 and 3D2, 3D5. Thus only CH1 signals are fed to the vertical output amplifier via OR gates 3D4 3D14 and 3D5, 3D15.

(ii) CH2. Biased such that a gating input is fed to the two switched linear gates 3D13, 3D14 and 3D12, 3D15. Thus only CH2 signals are fed to the vertical output amplifier via OR gates 3D4, 3D14 and 3D5, 3D15.

(iii) CH1 + 2. Biased such that a gating input is fed to all four switched linear gates. Thus CH1 and CH2 signals are fed to the vertical output amplifier via the two OR gates.

(iv) ALT. In this case, the MODE switch removes a bias from the alternate mode trigger shaper, the output of which then sets and resets the bistable on alternate timebase sweeps. The gating input to the pairs of switched linear gates changes accordingly, and thus CH1 then CH2 signals are fed, via the two OR gates, to the vertical output amplifier on alternate timebase sweeps.

(v) CHOP. In this case, the vertical mode oscillator switches the bistable independently of the timebase at approximately 200 kHz. The gating input to the pair of switched linear gates changes accordingly, and thus CH1 and CH2 signals are fed, via the two OR gates, to the vertical output amplifier many times per timebase sweep.

(h) Whenever the bistable changes state on the CHOP vertical mode, the chop oscillator provides an input, via emitter follower 2VT12, to the c.r.t. blanking amplifier to blank the c.r.t. during the switching period.

(i) The output from the combining and selecting gate diodes is fed to the vertical output amplifier via a delay line, DL1. This introduces a 180 ns delay to enable the leading edge of the pulse from which the sweep is derived to be displayed when internal trigger mode is selected. The vertical output amplifier consists of the common part of the cascode amplifier (Chapter 3.2.1(c)) this being coupled via emitter followers to a balanced cascode output amplifier. An internal control provides adjustment for frequency compensation.

3.2.2 Trigger System

(a) The required trigger signal is selected by the TRIG SOURCE switch (SC) and fed, via an input coupling switch (SD), to an impedance changer (2VT1 and 2VT2) of which the main component is a field-effect transistor.

(b) The trigger generator consists of a high-gain differential amplifier (2N1) connected as a d.c. operated switch (schmitt trigger), and a pulse shaper (2VT3 and 2N2-1). The polarity of the input to the Schmitt is controlled by the SLOPE control. The circuit divides at input triggering frequencies of approximately 2 MHz and above. When auto mode is selected, negative feedback is applied, via an integrating network, and the circuit then switches as the resultant triangular feedback waveform just passes through the hysteresis levels of the Schmitt trigger.

3.2.3 Horizontal Deflection System

(a) The timebase is controlled by the sweep bistable (2N2-2 and 2N2-3). This bistable is set by the sweep trigger, is reset at the end of the scan, and is then clamped for a hold-off period to allow the flyback to be completed before retriggering occurs.

(b) During the wait period (i.e. the period between the end of hold off and retriggering) the output of the bistable is at a positive level. Thus the output of inverter 2VT13 is at OV; 2D5 is therefore conducting and the capacitor selected by the TIME/cm switch (SH) is fully discharged.

(c) The selected capacitor, 2VT15, 2VT16, 2VT18 and 2VT19 form a bootstrap sweep generator in which the constant-voltage power supply is controlled by RV4 (TIME/cm VAR).

(d) The timebase sweep is initiated by the sweep trigger which sets the bistable so that the output of inverter 2VT13 changes to a positive level: this reverse biases 2D5. The selected sweep capacitor now begins to charge linearly, the charging current being set by the constant-voltage power supply and the selected resistor.

(e) At a predetermined point, the output of the sweep hold-off (2N2-4, 2VT17, 2VT20) changes from a positive level to a 0 V level. This resets bistable 2N2-2 and 2N2-3 and the output from 2VT13 reverts to a positive level. 2D5 conducts and rapidly discharges the selected sweep capacitor. The hold-off period required is dependent upon the time that the capacitor requires to discharge through 2D5 and, at the end of the hold-off period, the output of the sweep hold-off reverts to a positive level. Thus bistable 2N2-2 and 2N2-3 can be set by the next sweep trigger.

(f) If a sweep trigger occurs near the instant the hold-off period ends (e.g. at high triggering frequencies), then the hold-off period can be adjusted by RV3 (HF SYNC) to obtain a stable display.

(g) The input to the X amplifier (2VT22 to 2VT28) is controlled by the sweep mode switch (SF); on external a.c. or d.c. modes, the input is obtained from SKT E (X IN); on internal mode, the input is obtained from the sweep generator. 2VT22 to 2VT28 form a cascode amplifier which provides a balanced output to the c.r.t. X plates. 2VT21 provides the high input impedance necessary when external sweep mode is selected.

(h) When the sweep bistable (2N2-2 and 2N2-3) is reset, the positive-going change of level at 2TP7 is shaped by 2VT10 and fed as the alternate-mode trigger waveform, to the vertical mode bistable (Chapter 3.2.1.(g)(iv)). In addition, this change of level, inverted by 2VT13 is fed via emitter follower 2VT14, as a blanking input to the c.r.t. blanking modulator (2VT4 to 2VT6), the other input being fed from the chopped-blanking emitter follower 2VT12 (Chapter 3.2.1 (h)). Blanking is therefore applied to the c.r.t.:-

(i) At the end of sweep.

(ii) Whenever the chop oscillator changes state (i.e. CHOP mode).

3.3 CIRCUIT DESCRIPTION

3.3.1 Trigger (Figs. 7.3, 7.4 and 7.5)

(a) The selected trigger input is applied to the gate of field-effect transistor 2VT1 whose operating condition is set by 2RV8, in conjunction with Link 1, so that the quiescent level at 2TP1 is 0 V. 2R2, in conjunction with 2D1, provides overload current limiting and prevents damage to 2VT1 by large-amplitude trigger pulses, while 2C1 is a speed-up capacitor. A large amount of negative feedback is applied to 2VT1 by 2VT2 and 2R5: this reduces the output impedance of 2VT1 and prevents drift. The high-frequency sensitivity of the trigger circuit is reduced when vertical mode CHOP is selected. SMd then removes the bias from 2VT11, which then

provides a low-impedance path (through 2C30) to any high-frequency components in the trigger signal (i.e. edges derived from the chop-oscillator waveform, especially), thus preventing incorrect triggering on this mode.

(b) 2N1 is a high-gain differential amplifier to which positive feedback is applied via 2R12 and 2C5: the circuit therefore operates as a d.c. operated switch (Schmitt trigger) in which the switching levels of the characteristic (the hysteresis levels) are defined by 2R12 and the source impedance presented to pin 14 of 2N1. 2D13 and 2D14, in conjunction with 2R6, provide input voltage limiting. Negative feedback may also be applied, integrated by 2R13 and 2C4, via 2R9 (para 3.3.1 (c), (ii) and (iii)).

(c) The generation of a trigger event at 2TP6 is dependent upon the trigger mode selected: the operation of the circuit is therefore best explained with reference to the simplified diagrams of Fig 3.1 (a) , (b) and (c).

(i) A.C. and d.c. trigger mode (Fig 3.1 (a)). The auto feedback loop, 2R13, 2C4 and 2R9, is inhibited by SDc and SFb, and the input to 2N1 consists of the trigger waveform to which a d.c. level, set by the level control (RV1) has been added. The setting of SE determines the slope of the trigger waveforms on which 2N1 switches: the hysteresis points are defined by 2R12 and R3 if negative slope is selected, and by 2R12, 2R8 and 2R6 if positive slope is selected. 2N1, therefore, is switched at a point on the required slope of the trigger waveform set by the level control, i.e. this point is d.c. shifted about 0 V, approximately.

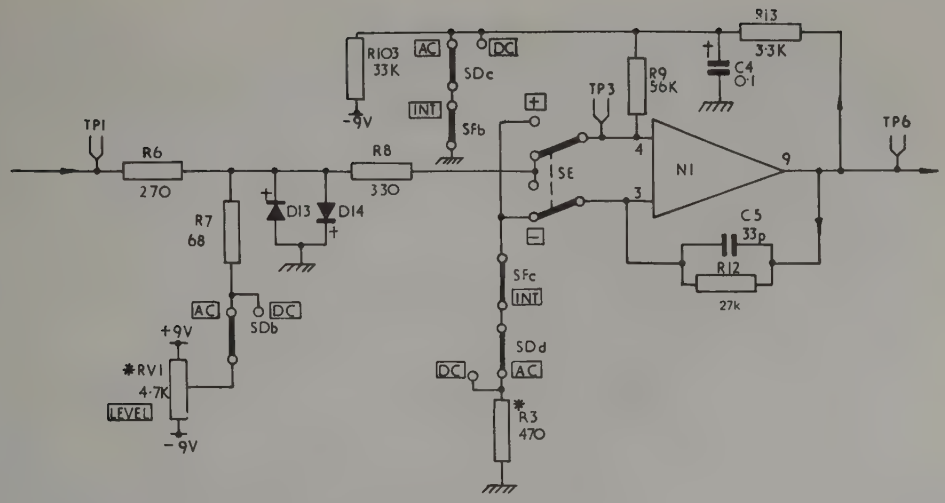
The output at 2TP6, consists of a positive-going event, coincident with the selected part of the trigger waveform, of which the maximum p.r.f. is determined by the time constant 2C5 and R3 (negative slope selected) or 2C5, 2R8 and 2R6 (positive slope selected). This p.r.f. is approximately 3 MHz, and if the p.r.f. of the trigger input exceeds this frequency the trigger is counted down. This prevents loss of sweep trigger at frequencies above the maximum frequency at which 2N1, 2VT3 and 2N2 can operate.

(ii) Auto trigger mode (Fig. 3.1 (b)). In this mode, negative feedback integrated by 2R13 and 2C4, is applied to pin 4 (the inverting input) of 2N1. The resultant integrated waveform at pin 4 is triangular in shape, and rises and falls within the upper and lower hysteresis levels of the d.c. operated switch. When the level of the waveform reaches either of the two hysteresis levels, the switch changes state.

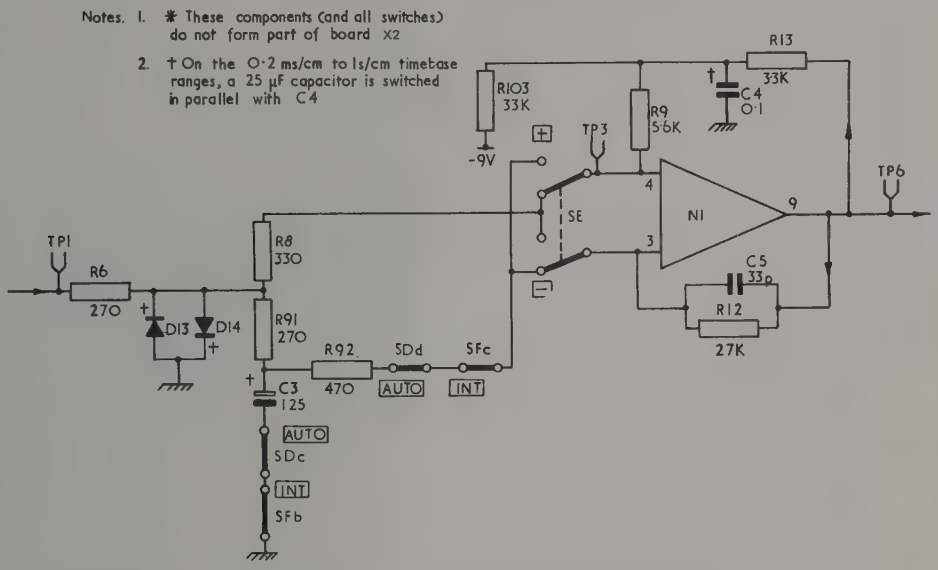
The d.c. level of both inputs of 2N1 is approximately 0 V, i.e. that at 2TP1 (para (a)), as the d.c. component of any trigger input present is removed by C3 (SDa being in the AUTO position). The a.c. component of the trigger signal, however, is fed to one input, only, of 2N1, 2C3 removing this component from the other input.

The inverting input of 2N1 is therefore a triangular waveform, centred about 0 V: the a.c. component of the trigger signal from 2R8 is superimposed upon this waveform (negative slope selected), or upon the in-phase input, pin 3 (positive slope selected). Hence, although the auto trigger rate is dependent upon the time constant 2R13, 2C4, it is also dependent to a lesser extent upon the amplitude and p.r.f. of the trigger signal. However, the p.r.f. of the trigger signal must be greater than that of the free-running auto trigger rate.

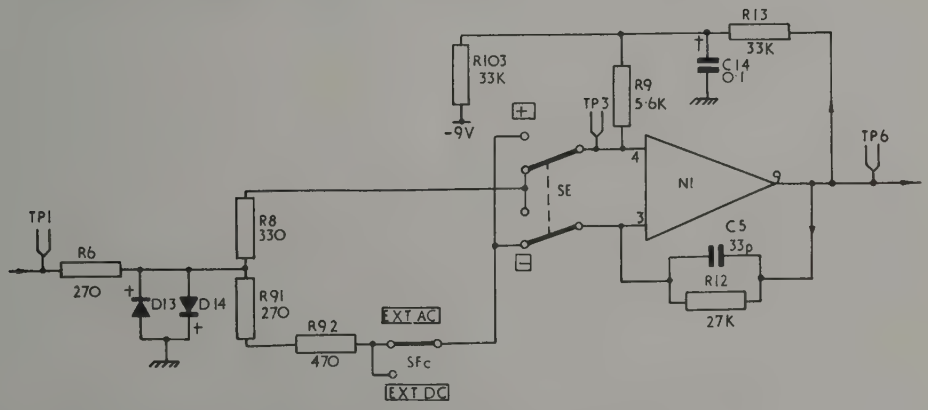
On the slower timebase ranges (1 s/cm to 0.2 ms/cm), C13 is placed in parallel with 2C4, by wafer SHf of the TIME/cm switch. This ensures that the auto trigger rate is commensurate with the selected timebase sweep.



(a) A.C. OR D.C. TRIGGER MODES (AC.MODE SHOWN) SIMPLIFIED DIAGRAM.



(b) AUTO TRIGGER MODE – SIMPLIFIED DIAGRAM.



(c) EXTERNAL SWEEP MODE – SIMPLIFIED DIAGRAM.

Fig. 3.1 Operation of the Trigger Circuits, Mode Selection

(iii) External sweep (Fig 3.1 (c)). When the instrument is used with an external sweep the trigger generator is effectively placed in the auto mode, irrespective of the position of the trigger mode switch. In this case, 2C3 is open-circuited and both inputs to 2N1, via SE, are at the same d.c. (and a.c.) level. The circuit then operates at the free-running auto trigger rate and ensures that sweep triggers are available to hold the sweep bistable (2N2-2 and 2N2-3) in the set position, thus maintaining the c.r.t. in an unblanked condition during external sweep.

(d) 2VT3 is a pulse shortener and 2N2-1, a pulse shaper, performs a 'positive NAND' function. A truth table is shown below, referring to gate 2N2-1 in Fig 3.2.

Input (1)	Input (2)	Output (3)
1	0	1
1	1	0
0	1	1

In the period before a positive-going trigger event at 2TP6 occurs (Para 3.3.1 (c) (i) 2VT3 is non-conducting: pins 1 and 2 of 2N2-1 are therefore at logic 1 and logic 0 respectively, so that pin 3 is at logic 1 (i.e. positive level). When 2TP6 becomes positive, pin 2 changes to logic 1 and pin 3 falls to logic 0 for a period determined by the time constant 2R15, 2C6. After this period, 2VT3 conducts, pin 1 falls to logic 0, and pin 3 returns to logic 1 and remains at this level as 2N1 switches back to the wait state. Thus a trigger pulse, 100 ns in duration, is generated at 2TP5 for every positive-going transition at 2TP6.

3.3.2 Horizontal Deflection System (Figs. 7.3, 7.4 and 7.5)

(a) Logic packages. The SN7400N (or FJH131) package used in the trigger and sweep generator circuits perform a positive NAND function, i.e. if all inputs to a gate are logic 1 (not less than +2.4 V), the output will be logic 0 (not greater than +0.4 V). For all other input conditions, the output will be logic 1. Fig. 3.2 and Table 3.1 shows the sequence of operation of the package for all possible input conditions.

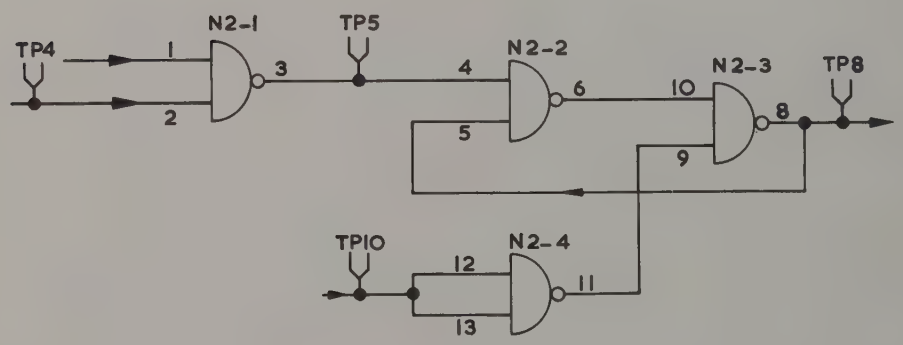


Fig 3.2 Integrated Package - Logic Diagram

Element and pin Nos	Wait or end of hold-off	On trigger	During sweep	End of sweep or during hold-off
1	1 or 0	1	1 or 0	1 or 0
N2-1 2	0 or 1	1	0 or 1	0 or 1
3*	1	0	1	1
4	1	0	1	1
N2-2 5	1	0	0	1
6*	0	1	1	0
8*	1	0	0	1
N2-3 9	1	1	1	0
10	0	1	1	0
11*	1	1	1	0
N2-4 12	0	0	0	1
13	0	0	0	1

* element output pin

Table 3.1 Sequence of Operation

(b) Sweep generator. During the wait period (i.e. the period between hold-off and retriggering), the output of 2N2-4, the input at pin 4 of 2N2-2 and the output of 2N2-3 are each at logic 1. 2VT13, therefore, is conducting, 2D5 is forward biased, and the capacitor selected by wafer SHd of the TIME/cm switch is fully discharged.

(c) The timebase sweep is initiated by the sweep trigger: this sets the bistable; the output of 2N2-3 changes to logic 0 and 2D5 is reverse biased via 2VT13. The selected sweep capacitor now begins to charge linearly through one of R8 to R13, the charging current being set by constant-voltage power supply 2VT18, 2VT19. This constant voltage is itself determined by one of 2RV4, 2R55, 2RV6 or 2RV5, depending on the selected sweep, to allow for tolerances on the sweep capacitors.

(d) Commencing at the slowest timebase ranges, the first three positions of wafers SHd and SHe each cover six ranges, and wafer SHa inserts R8 to R13, in turn, into the charge path as the TIME/cm switch selects a faster range. The fourth position of wafers SHd and SHe covers the three fastest timebase ranges, and wafer SHb inserts R11 to R13, in turn, into the charge path, the charging capacitor being 2C17 alone. The effect of this capacitor in parallel with 2C14, 2C15 or 2C16 is offset by 2RV4, 2R55 and 2RV6.

(e) The output of drain follower 2VT15 is fed via emitter follower 2VT16 to hold-off circuit 2VT17 and monostable 2N2-4, 2VT20, and also via SF to the X amplifier.

(f) During the wait and sweep periods 2VT20 is conducting, and the input to 2N2-4 is held at logic 0. The length of sweep is set by 2RV3 so that when the base of 2VT17 has risen to approximately +2 V (i.e. logic 1 at pins 12 and 13 of 2N2-4), the output of 2N2-4 changes to logic 0. This resets bistable 2N2-2, 2N2-3, and 2D5 conducts and rapidly discharges the selected sweep capacitor.

(g) The hold-off required is dependent upon the time that the selected sweep capacitor takes to discharge through 2D5 and 2VT13. 2R61 and 2C19 in parallel with the capacitor selected by wafer SHc form the time constant for the hold-off period (on the three fastest timebase ranges,

2C19 only, is the selected capacitor), and the end of hold-off is controlled to provide stable sweep triggering. Positive-going pulses, derived from the logic 1 outputs at pin 6 of 2N2-2 which occur when triggers are generated during hold-off, are applied to 2VT20 emitter via 2C31 and 2R97. These pulses prevent the monostable from reverting to its stable state near or during the instant a trigger occurs. However, at high triggering frequencies, additional control is provided by RV3 (HF SYNC). This enables the aiming potential, and thus the hold-off period, to be adjusted so that the next sweep is not initiated immediately the hold-off period ends.

(h) X amplifier. The sweep waveform at 2TP8 is fed, via SFa (SF set to INT SWEEP) and source follower 2VT21, to the X amplifier (2VT22 to 2VT28), which converts the single-ended input at 2VT23 to a balanced output to the c.r.t. X plates. The operating conditions of the amplifier are such that the mean potential of the X plates is similar to that of the Y plates. 2C27 and 2R28 provide high-frequency compensation.

(i) When SG is switched to x1, the overall gain of the sweep generator and X amplifier is determined by RV5 (CAL x1), RV4 (TIME/cm VAR) being set to CAL. RV5 is set on the 10 ms/cm range, the voltage of the constant-voltage power supply then being determined by 2R55. The x5 gain is then adjusted accordingly.

(j) If SF is set to either the EXT AC or EXT DC positions, 2VT21 provides a high input impedance, via wafer SFa, to an input at SKT E. Wafer SFb short-circuits the capacitor selected by the TIME/cm switch and wafer SFc effectively places the trigger circuit in the auto mode: this provides an infinitely long internal timebase sweep to maintain the c.r.t. in an unblanked condition during external drive.

(k) C.R.T. modulation. 2VT4 to 2VT6 form a modulation pulse generator consisting of a d.c. amplifier (2VT4 and 2VT6) and a complementary current switch (2VT5). There are two inputs to each section of the pulse generator, these being the sweep gating waveform via emitter follower 2VT15 and chopped-blanking gating via emitter follower 2VT12.

(l) 2RV1 is adjusted so that a modulation level of approximately +9 V (i.e. maximum brightness) applied to the c.r.t. blanking plate, unblanks the c.r.t. during the sweep period, or, if CHOP vertical mode is selected, on the positive going excursions of the chopped-blanking waveform during the sweep period. The gain of the d.c. amplifier to the sweep gating and chopped-blanking inputs is approximately 6 and 12, respectively.

(m) The edges of the input waveforms, after differentiation by 2C7, 2R23 or 2C8, 2R23, rapidly switch the current in 2VT5 (and thus 2VT6) to improve the rise and fall times of the modulation pulse. 2C10 provides an additional current source for 2VT5 as this transistor is switched into heavier conduction on removal of the blanking from the c.r.t. The improvement in rise and fall times ensures that the c.r.t. is rapidly unblanked and blanked at the beginning and the end of a timebase sweep, or, on CHOP vertical mode, as chopped switching occurs.

3.3.3 Vertical Deflection System (Figs. 7.6, 7.7, 7.8)

(a) The vertical deflection system consists of two identical channels (CH1 and CH2), each of which comprises an attenuator sub-unit (CH1 - attenuator X5: CH2 - attenuator X6), a pre-amplifier and a trigger pick-off amplifier. The outputs of each channel are switched, dependent upon the vertical mode selected, via a delay line and a vertical output amplifier, X4, to the c.r.t. Y plates. The following description of the attenuator, pre-amplifier and trigger pick-off refers to channel 1 only; that of the signal selection and the output amplifier includes the signals of both channels.

(b) Attenuator (Fig 7.6). The input signal is fed via SKTF (CH1 IN) and SN (input coupling) to wafer 5SAa of the CH1 V/cm switch. On the 0.02 V/cm range of 5SA, the signal is fed,

unattenuated, via the four wafers 5SAa to 5SAd, to source follower 3VT1 in the pre-amplifier: on all other ranges it is attenuated by amounts varying from 2.5:1 on the 0.05 V/cm range to 2500:1 on the 50 V/cm range. For example, on the 5 V/cm range, the signal is first attenuated by 100:1 in the network in which 5R3 is the series resistor, then further attenuated by 2.5:1 in the network in which 5R8 is the series resistor, parallel loading by the 1 megohm input resistance of the subsequent network being considered in each case.

(c) Trimming capacitors 5C3, 5C7, 5C11, 5C15 and 5C18 provide frequency response compensation by equalising the series and shunt time constants. Trimming capacitors 5C1, 5C5, 5C10, 5C13, 5C16 and 3C1 allow a constant input capacity to be maintained independent of the range selected, thus allowing the use of an external probe.

(d) Channel 1 pre-amplifier (Fig 7.7). The input signal, suitably attenuated, is fed to the gate of source follower 3VT1 to which negative feedback, to reduce the output impedance, is applied by 3VT2. 5R12 is an overload current limiter and prevents damage to 3VT1 by large-amplitude inputs while 5C19 is a speed-up capacitor. 3D1 provides further protection for 3VT1. Any gate leakage current is offset by 3RV1 such that the output of the pre-amplifier, and thus the d.c. level to the c.r.t. does not change between short-circuit and open-circuit input conditions.

(e) The signal at 3VT3 base is converted into a balanced output by differential amplifier 3VT3 to 3VT5, in which 3VT4 forms a constant-current source. The potential at 3VT5 base is determined, via emitter follower 3VT6 and 3VT33, by 3RV3 (coarse balance), RV6 (BAL) and 5RV1 (SHIFT). 3VT33 and 3VT6 have similar temperature coefficients and thus 3VT5 base is maintained at the level set by 3RV3 and RV6, minimising drift. These two controls enable the amplifier to be balanced so that the trace does not shift when switch SJ is operated.

(f) The outputs from 3VT3 and 3VT5 are fed, via emitter followers 3VT7 and 3VT8, to 3VT9 and 3VT10 which, in conjunction with 4VT1 and 4VT3, form a cascode amplifier. RV8 (V/cm FINE) provides continuously-variable control of the gain over a range in excess of 2.5:1 and, in the fully-clockwise position (CAL), direct measurement of the input signal can be made in conjunction with 5SA, (Note: In channel 2, operation of 3SL (PULL TO INVERT) changes the sense of the output from 3VT22 and 3VT23 and so provides signal inversion, when required, on this channel).

(g) The outputs from emitter followers 3VT7 and 3VT8 are also fed to trigger pick-off amplifier 3VT11, 3VT12. 3VT11 acts as a current source for virtual-earth amplifier 3VT13, the gain of which is determined by the negative-feedback resistor 3R43. The d.c. level at 3TP6 (3VT13 emitter) is 0 V, set by 3RV7 (trigger centre), so that the input conditions of the trigger generator on d.c. trigger mode are maintained constant, independent of the trigger source selected.

(h) Signal selection. The signal applied via delay line DL1 to the vertical output amplifier can be: from one of the signal channels (CH1 or CH2 modes); composite, from both channels (CH1 + 2 mode); switched alternately from each channel (ALT or CHOP modes). In all modes the biasing level of bistable 3VT27 and 3VT28 is controlled by SM (MODE), the bistable then determining the state of the combining and selecting gates 3D2 or 3D5 (channel 1) and 3D12 to 3D15 (channel 2).

(i) CH1 (Fig 3.3 (a)). 3VT27 base is returned via 3R90 and SMb to -40 V, and 3VT28 base is returned via 3R91 and SMa to -9 V. No triggering input is present at 3TP18, the chop oscillator, 3VT29 and 3VT30, being held inoperative by SMc and the alternate trigger shaper, 2VT10, being held in a non-conducting state by SMd 3VT27 and 3VT28 are therefore held in one state, with 3VT27 non-conducting and 3VT28 fully conducting. 3D2 and 3D3 are thus reverse biased with 3D4 and 3D5 forward biased, while 3D12 and 3D13 are forward biased and 3D14 and 3D15 reverse biased. The channel 1 signal, only, is thus fed to the vertical output amplifier.

(ii) CH2 (Fig 3.3 (b)). In this mode the circuit action is similar to that of channel 1 but the biasing of 3VT27 and 3VT28 is reversed, 3VT27 base being returned to -9 V and 3VT28 base to - 40 V. This, in turn, changes the biasing conditions of the combining and selecting gates, and thus the channel 2 signal, only, is fed to the vertical output amplifier.

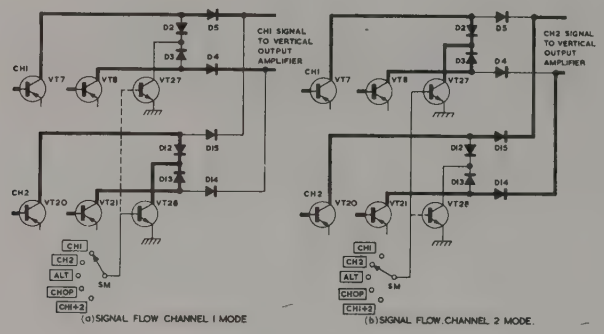


Fig 3.3. Combining and Selection Gating (Simplified Diagrams): Effective Signal Paths.

(iii) CH1 + 2. Sma and SMb return the bases of 3VT28 and 3VT27 to -40 V so that each transistor is biased into non conduction. 3D2, 3D3, and 3D12, 3D13 are then reverse biased with 3D4, 3D5 and 3D14, 3D15 forward biased, so that the output, at 3TP9 and 3TP10, consists of a composite channel 1 and channel 2 waveform. 3R99 is switched in parallel with 3R36 by SMd to offset, by potential division, the effect of the increase in bias on 4VT1 and 4VT2 due to the increase in current through 3R33, 3R39, 4R2, 4R3 and these transistors, as the two channels are switched into circuit.

(iv) ALT. In this mode SMd removes the bias from 2VT10, and SMa and SMb return the bases of 2VT28 and 2VT27 to -9 V. Negative-going pulses at 3TP18, derived via 2C12, 2R40 and 2VT10 from the change in level to logic 1 at 2TP8 (2N2-3 pin 8) at the end of sweep, are differentiated by 3C29, 3R89 and 3C31, 3R93. The negative-going component, fed via 3D19 and 3D20 to 3VT27 and 3VT28 bases, switches the relevant conducting transistor into non conduction and the bistable changes state. Any transients generated during switching therefore occur during the timebase hold-off and wait period (i.e. c.r.t. blanked).

(v) CHOP. The current path for 3VT30 is completed via SMc in this mode, 3VT29 and 3VT30 then forming an emitter-coupled astable of approximate p.r.f. and mark-to-space ratio of 200 kHz and 3:1 respectively. During the switching period, negative-going 1, 2 μs pulses from 3VT30 (3TP20) are fed via emitter follower 2VT12 to the c.r.t. modulation circuit. Similar pulses (3TP18), inverted by 3VT32 from the output of 3VT29 (3TP19), are fed to 3VT27 and 3VT28 and switch the bistable as described in Para. h (iv), i.e. switching during c.r.t. blanking. The chopped portions of the signals displayed on each channel are thus approximately 3.7 μs in duration.

(vi) Output amplifier. 4VT1 and 4VT3 form the common part of the cascode amplifier in conjunction with 3VT9, 3VT10 (channel 1) or 3VT22, 3VT23 (channel 2). Negative feedback, applied via 4VT2, 4R7 and 4VT6, 4R24, maintains the d.c. conditions of the amplifier and thus of the balanced output to the c.r.t. Y plates. The gain of output cascode amplifier 4VT4, 4VT5, 4VT7 and 4VT8 is determined by 4R14; the remaining components coupling the emitters of 4VT4 and 4VT8 provide frequency compensation.

3.3.4 Power Unit (Fig. 7.9)

(a) The input line supply is connected to PLA, switched by SA, fused by FS1, and connected via the voltage selector switch SB, dependent upon the supply voltage, to the primary windings of T1. The output of T1 is full-wave rectified by D2 and D3 to provide a d.c. voltage of approximately +24 V at 1TP1.

(b) VT1, VT2 and 1T1 form a conventional d.c./d.c. converter which oscillates at approximately 3 kHz. The input supply voltage (1TP3) is dependent upon the voltage drop across series regulator VT3 (Para. (c)) due to the load current. With the exception of the c.r.t. heater circuit, the outputs of the secondary windings of 1T1 are rectified as follows:-

(i) +9 V: full-wave rectified by 1D6 and 1D8.

(ii) -9 V: full-wave rectified by 1D7 and 1D9.

(iii) -3 kV: voltage quadrupled by 1D10 to 1D13.

(iv) -1 kV: voltage quadrupled by 1D14 to 1D17.

(v) +140 V: half-wave rectified by 1D18.

(vi) +80 V (+75 V): half-wave rectified by 1D19.

(vii) -40 V: half-wave rectified by 1D20.

(viii) +20 V: half-wave rectified by 1D21.

(c) Stabiliser. Voltage control is provided by 1VT1 to 1VT5 and VT3. The input at 1VT4 base consists of a sample portion of the +20 V output voltage provided by potential divider chain 1R9, 1RV1 and 1R10, and of a sample portion of the +9 V output voltage before smoothing. The current in 1VT4 (and thus in 1R5) is determined by these inputs and any transient variations (a.c) in the +20 V or +9 V lines or long-term variations (d.c) in the +20 V line cause a proportional change in current in 1VT2. 1VT3 provides a constant-current source for 1VT1 and 1VT2, this current being the sum of 1VT1 base current and 1VT2 collector current. 1VT1 base current is thus the difference between the constant current and the generated error current. Emitter follower 1VT1, in turn controls series regulator VT3 so that an increase in current in 1VT4, due to a negative-going fluctuation on the +9 V or +20 V lines, causes an increase in the conduction of VT3. Since VT3 is effectively in series with the converter output, the decrease in its impedance (i.e. increase in output voltage) tends to counteract the reduced input voltage to 1VT4. Conversely, if the input to 1VT4 increases, the impedance of VT3 will be increased.

(d) Any tendency for 1VT4 current to drift is offset by 1VT5, an identical transistor type, in which the forward-biased base-emitter junction is used for temperature compensation. The characteristics of 1D1 and 1D2 are also used to maintain the constant-current source with temperature.

(e) Battery operation. When the oscilloscope is operated from an external battery or from a Battery Pack, the line rectifying circuit is bypassed and the battery voltage provides the supply for the d.c./d.c. converter. 1R19 permits the oscilloscope to be operated from either a positive or negative-ground battery supply the voltage at 1TP3 and 1TP2 being 0 V and approximately -18 V respectively for a positive-ground supply, and approximately +18 V and 0 V for a negative-ground supply.

3.3.5 Calibrator (Fig. 7.3)

The voltage calibrator consists of an emitter-coupled astable 2VT7 and 2VT8 which oscillates at 1 KHz set by 3RV2, and an amplifier 2VT9. Potential divider 2R34 to 2R37 ensures that as 2VT9 is switched between its fully-conducting and non-conducting states accurate voltage outputs of 1 V and 100 mV are provided at SKTA and SKTB respectively.

3.3.6 C.R.T. Circuit (Fig. 7.2 Sheet 2)

(a) RV12 (FOCUS) is positioned approximately centrally in a potential divider connected between 0 V and -1 kV, the voltage at its wiper being applied to the c.r.t. focusing anode. This control is adjusted in conjunction with RV14 (ASTIG) to achieve optimum beam spot size on the screen. The c.r.t. total beam current is set by RV13 (BRILL), and D4 acts as a constant-voltage supply, maintaining the voltage across RV13, and thus across RV12, for different settings of RV13.

(b) Pin-cushion or barrel distortion is minimised by 2RV9 (geometry adjust).

(c) The c.r.t. heater is powered from an a.c. supply derived from a separate winding on 1T1. This supply is referenced to the negative e.h.t. supply at the c.r.t.

(d) RV16 (TRACE ROTATE) determines the amplitude and direction of the current in L1 and so permits the c.r.t. trace to be aligned with the graticule.

Chapter 4

Maintenance

4.1 INTRODUCTION

This section contains information on preventive maintenance and performance checks to ensure that the instrument will continue to meet its specification.

The performance checks which can be made without the cover being removed may be used to provide symptoms of fault conditions (more fully outlined in chapter 5).

Reference should be made to chapter 3.1 for the system of component coding used in this manual.

WARNING Do not remove the cover unless the instrument is disconnected from the a.c. supply (or battery, if d.c. operated). When the instrument is withdrawn from its case and power applied, access is immediate to dangerous voltages:

(a) 250 V AC derived from the a.c. supply.
(b) +3 kV DC from 1T1 (c.r.t./p.d.a. voltage)
(c) -1 kV DC from 1T1 (c.r.t. cathode voltage)

4.2 PREVENTIVE MAINTENANCE

This includes cleaning, visual inspection and lubrication and if performed periodically, may prevent breakdown. The frequency of maintenance is determined by the environment to which the oscilloscope is subjected, and a convenient time is preceding recalibration.

Periodically inspect the oscilloscope for mechanical defects (e.g. on rotary switches or support brackets), for broken connections, including the printed wiring on the circuit boards, and for evidence of overheated components.

4.2.1 Access

The oscilloscope consists of a cruciform frame, formed by four bulkheads of sheet aluminium to which the front and rear panels are bolted. The structure is made rigid with four tie bars of extruded aluminium fitted axially between the corners of the front and rear panels. A false front panel displays the control annotations.

The cover is in one piece and is made of sheet aluminium covered in dark-grey, vinyl plastic. At the rear of the front panel, it locates into grooves which are partially sealed with rubber gaskets, and it is secured to the rear panel by eight screws. The majority of screws used on this instrument have UNC threads.

The circuit components, with exception of the front panel controls and Y input attenuators, are mounted on four fibreglass, printed-circuit boards. Three of these boards are hinged so that both sides can be accessible for servicing purposes; both sides of the other board can be easily reached in situ.

4.2.2 Cleaning and Lubrication

Dust accumulation within the oscilloscope, due to its heat-insulating effect on components, can cause reduced heat dissipation and thus breakdown. In conditions of high humidity its electrical conductivity increases, so that high-voltage arcing may occur on or around components associated with the two e.h.t. supplies.

A dry, low-velocity air line is recommended for removing dust, a small brush being particularly useful for dislodging dirt in inaccessible places such as switch wafers and on or under front-panel controls.

The occasional use of an approved lubricant (one that does not affect electrical or mechanical characteristics) can help to maintain the reliability of moving parts (e.g. rotary switches and potentiometers). Do not overlubricate. Panclimatic grease should be used to lubricate concentric shafts.

4.3 PERFORMANCE CHECKS

These checks refer to the adjustment of front panel controls (including preset controls). During the tests, control setting or test equipment connections should not be changed except as instructed.

Where checks are identical for channels 1 and 2, channel 2 component references (or control annotations, etc.,) are quoted in brackets, immediately following the channel 1 component reference.

4.3.1 Test Equipment Required

The following test equipment is required to carry out the performance checks:-

(a) An oscilloscope calibrator. Except where stated, the voltage output is set to squarewave (1 kHz).

(b) A low-frequency sinewave generator. Frequency variable between 1 kHz and 50 kHz and output variable between 0 V and 10 V when loaded with 1 MΩ. A TF 1370A is suitable.

(c) Constant-amplitude oscillator. Frequency variable between 50 kHz and 15 MHz, output variable between 0 mV and 1 V. A TF 2002AS or TF 144H is suitable.

(d) Oscilloscope with similar specification to the TF 2204.

4.3.2 Preliminary Settings

(a) Ensure that the input voltage selector is set to 230 V and that fuse links FS1 (500 mA) and FS2 (2 A) are correctly positioned and in good order.

(b) Connect the oscilloscope to a 230 V AC supply.

(c) Set:-

(i) BRILL fully counter-clockwise.

(ii) TRIG MODE to AUTO; TRIG SOURCE to CH1; SLOPE to +.

(iii) TIME/cm to 1 ms/cm; TIME/cm VAR to CAL; EXPAND to x1; INT SWEEP.

(iv) MODE to CH1.

(v) CH1 V/cm to 0.5 V/cm; V/cm FINE to CAL; GAIN to x1; AC.

(vi) CH2 V/cm to 0.02 V/cm; V/cm FINE to CAL; GAIN to x1; GND.

(vii) PULL TO INVERT pushed in.

(d) Set SUPPLY downwards (on). Check that the SUPPLY lamp glows and allow the oscilloscope five minutes to stabilise.

4.3.3 Cathode Ray Tube

(a) Connect the voltage output of the test oscilloscope calibrator, output amplitude 2 V, to CH1 IN.

(b) Advance BRILL until the intensity of the trace is adequate and adjust FOCUS and ASTIG to obtain a well defined trace.

NOTES: 1 To increase the life of the c.r.t. do not turn BRILL higher than necessary for a satisfactory display.

2 To check for correct setting of the ASTIG control, slowly turn FOCUS through the optimum setting. If the ASTIG adjustment is correct, the horizontal and vertical portions of the channel 1 trace will come into sharpest focus at one position of the FOCUS control. The setting of the ASTIG control should then be correct for any display.

(c) Adjust CH1 SHIFT to position the display about the central horizontal graticule line. If necessary adjust TRACE ROTATE to set the display parallel with the horizontal graticule lines.

(d) Disconnect the test oscilloscope calibrator.

4.3.4 Channel 1 (Channel 2) Balance

(a) Set:-

(i) MODE to CH1 (CH2)

(ii) CH1 (CH2) V/cm to 0.02 V/cm; V/cm FINE to CAL; GAIN to x1; AC.

(iii) SHIFT, 5RV1 (6RV1), to centre of travel.

(iv) Other controls as detailed in 4.3.2 (c) (ii), (iii), (vii).

(b) Check that the range on BAL, RV6, (RV7), is such that it will position the trace anywhere within the vertical limits of the graticule.

(c) Set GAIN, SJ (SK), to x10 and check that the trace can be centred with BAL, RV6 (RV7).

(d) Adjust BAL, RV6 (RV7) so that on switching GAIN, SJ (SK), between the x1 and x10 positions any vertical movement of the trace is less than 2 mm. Reset GAIN, SJ (SK), to x1.

(e) Check that the range of SHIFT, 5RV1 (6RV1), is such that it will position the trace anywhere within the vertical limits of the graticule.

4.3.5 Channel 1 (Channel 2) Gain

(a) Connect the voltage outputs of the test oscilloscope calibrator output amplitude 120 mV, to CH1 IN (CH2 IN).

(b) Centralise the display with SHIFT, 5RV1 (6RV1). Set the amplitude of the display to 6 cm with SET CAL, RV9 (RV11).

(c) Set V/cm FINE, RV8 (RV10), fully counter-clockwise. Check that the amplitude of the display is less than 2.4 cm. Reset V/cm FINE to CAL.

(d) Set the voltage output of the calibrator to 0 mV, +, and switch CH1 (CH2) input coupling to DC.

(e). Set the voltage output of the calibrator to 120 mV, +. Check that the shift in displayed level is +6.1 cm ±0.1 cm.

(f) Set the voltage output of the calibrator to 12 mV, and GAIN, SJ (SK), to x10. Check that the amplitude of the display is 6 cm. Return GAIN x1.

4.3.6 Channel 1 (Channel 2) Attenuators

(a) Set:-

(i) MODE to CH1 (CH2)

(ii) TRIG MODE to AUTO : TRIG SOURCE to CH1 (CH2): SLOPE to +.

(iii) CH1 (CH2) V/cm to 0.02 V/cm.

(b) Set the voltage of the test oscilloscope calibrator to 100 mV. Check that the amplitude of the displayed waveform is 5 cm ±1 mm and that any undershoot or overshoot present on the waveform is less than 1%.

(c) Repeat this check for the appropriate settings of the V/cm switch as detailed in Table 4.1 resetting the output of the test oscilloscope calibrator as indicated.

V/cm setting 5SA (6SA)	Oscilloscope calibrator output	Display amplitude (±1 mm)
0.05	250 mV	5 cm
0.1	500 mV	5 cm
0.2	1 V	5 cm
0.5	2.5 V	5 cm
1	5 V	5 cm
2	10 V	5 cm
5	25 V	5 cm
10	50 V	5 cm
20	100 V	5 cm
50	100 V	2 cm

Table 4.1. Attenuation Ratio Check

(d) Disconnect the test oscilloscope calibrator.

4.3.7 Vertical Mode

(a) Set:-

(i) CH1 and CH2 input coupling to GND

(ii) TIME/cm to 0.1 ms/cm

(iii) MODE to ALT.

(b) Check that alternate sweeps (one second duration) are under the control of CH1 SHIFT then CH2 SHIFT.

(c) Set MODE to CHOP. Check that two traces are visible, one under the control of CH1 SHIFT, the other under control of CH2 SHIFT.

(d) Set:-

(i) MODE to ALT.

(ii) CH1 and CH2 V/cm to 0.02 V/cm; AC.

(iii) TRIG SOURCE to CH1.

(iv) TIME/cm to 1 ms/cm.

(e) Connect the voltage output of the test oscilloscope calibrator, output amplitude 160 mV, to both CH1 IN and CH2 IN. Position both traces within the graticule with CH1 SHIFT and CH2 SHIFT.

(f) Set MODE to CH1 + 2, pull out PULL TO INVERT and adjust either CH1 or CH2 V/cm FINE to reduce the display amplitude to less than 1 mm peak.

(g) Reduce the test oscilloscope calibrator output to 80 mV and push in PULL TO INVERT. Check that the display amplitude is 8 cm $\pm$0.2 cm.

(h) Set CH2 input coupling to GND. Check that the display amplitude is 4 cm $\pm$0.1 cm.

4.3.8 Trigger Level

(a) Set:-

(i) TRIG SOURCE to EXT; TRIG MODE to AC; SLOPE to +.

(ii) MODE to CH1

(iii) CH1 V/cm to 1 V/cm FINE to CAL; GAIN to x1; AC.

(iv) Connect the sinewave generator, output frequency 1 kHz, and amplitude 6 V p-p to CH1 IN.

(b) Check that the start of the trace (i.e. triggering) can be adjusted by LEVEL to occur at any point on the positive-going slope of the waveform.

(c) Set SLOPE to — Ensure that triggering can be set by LEVEL to occur at any point on the negative-going slope of the waveform.

(d) Set CH1 V/cm to 2 V/cm and TRIG MODE to AUTO. Check the triggering point is on the negative-going slope near the centre of the waveform.

(e) Set SLOPE to +. Check that the triggering point is on the positive-going slope near the centre of the waveform.

4.3.9 Trigger Sensitivity and Response

(a) Set CH1 V/cm to 0.1 V/cm and the output of the test sinewave generator to 250 mV p-p. Check that stable triggering occurs.

(b) Set SLOPE to - Check that stable triggering occurs.

(c) Set TRIG MODE to AC. Check that stable triggering can be obtained, adjusting LEVEL if necessary.

(d) Set SLOPE to +. Check that stable triggering can be obtained, adjusting LEVEL if necessary.

(e) Set CH1 V/cm to 2 V/cm, TRIG SOURCE to EXT ÷ 20, and the output of the test sinewave generator to 5 V p-p. Check that stable triggering can be obtained, adjusting LEVEL if necessary. Disconnect the test sinewave generator and connect the test constant-amplitude oscillator to CH1 IN.

(f) Set:-

(i) TRIG SOURCE to EXT.

(ii) TIME/cm to 0.2 μs/cm.

(g) Set the output of the test constant-amplitude oscillator to 250 mV and the frequency to 5 MHz. Check that stable triggering can be obtained, adjusting LEVEL and HF SYNC as necessary.

(h) Set the output of the test constant-amplitude oscillator to 500 mV and the frequency to 15 MHz. Check that stable triggering can be obtained, adjusting LEVEL and HF SYNC as necessary. Disconnect the test constant-amplitude oscillator.

4.3.10 Trigger Source

(a) Set:-

(i) TRIG SOURCE to CH1 (CH2); TRIG MODE to AUTO; SLOPE to +.

(ii) MODE, to CH1 (CH2).

(iii) TIME/cm to 1 ms/cm.

(iv) CH1 (CH2) V/cm to 0.02 V/cm; AC.

(b) Connect the test sinewave generator, amplitude set to 36 mV, to CH1 IN (CH2 IN), i.e. signal amplitude of 1.8 cm. Set CH1 (CH2) V/cm to 0.2 V/cm and check that stable triggering can be obtained with SLOPE set to + and then to -.

(c) Set TRIG MODE to AC and check that stable triggering can be obtained on either position of the SLOPE switch, adjusting LEVEL if necessary.

(d) Set MODE to CHOP and check that stable triggering can be obtained. Disconnect the test sinewave generator.

4.3.11 Horizontal Gain and Sweep Length

(a) Set:-

(i) MODE to CH1.

(ii) CH1 V/cm FINE to CAL; GAIN to x1; AC.

(iii) TRIG MODE to AC; SLOPE to +; TRIG SOURCE to CH1.

(iv) TIME/cm to 1 ms/cm; TIME/cm VAR to CAL; EXPAND to x1.

(b) Connect the time output of the test oscilloscope calibrator, output period 1 ms, to CH1 IN. Set CH1 V/cm for a display amplitude of approximately 2 cm. If necessary, adjust LEVEL to obtain a stable display.

(c) Position the first marker (start of trace) on the left-hand vertical graticule line with X SHIFT. Check that the markers are 1 cm apart and that the second and tenth are aligned with the first and ninth vertical graticule lines from the left.

(d) Set TIME/cm VAR fully counter-clockwise. Check that the number of markers per cm increases to not less than $2\frac{1}{2}$. Reset TIME/cm VAR to CAL.

(e) Check that the overall trace length is approximately 11 cm. and that the start of the trace can be positioned anywhere within the horizontal limits of the graticule with X SHIFT.

(f) Set EXPAND to x5 and position the first marker on the left-hand vertical graticule line with X SHIFT. Check that the markers are 5 cm apart, i.e. the second and third align with the centre and right-hand vertical graticule lines, respectively. Reset EXPAND to x1.

4.3.12 Sweep Rate

(a) Set TIME/cm and the output period of the test oscilloscope calibrator as detailed in Table 4.2. Check that the number of markers displayed per cm are as indicated, to a tolerance of $\pm 2\%$.

TIME/cm setting	Oscilloscope calibrator output period	No of markers per cm
1 s	0.5 s	2
0.5 s	0.5 s	1
0.2 s	0.2 s	1
0.1 s	0.1 s	1
50 ms	50 ms	1
20 ms	20 ms	1
10 ms	10 ms	1
5 ms	5 ms	1
2 ms	2 ms	1
1 ms	1 ms	1
0.5 ms	0.5 ms	1
0.2 ms	0.2 ms	1
0.1 ms	0.1 ms	1
50 μs	50 μs	1
20 μs	20 μs	1
10 μs	10 μs	1
5 μs	5 μs	1
2 μs	2 μs	1
1 μs	1 μs	1
0.5 μs	0.5 μs	1
0.2 μs	0.2 μs	1

Table 4.2. Sweep Calibration Check

4.3.13 Sweep Out

(a) Connect the test oscilloscope to SWEEP OUT. Check that the observed waveform is sawtooth in form, rising by approximately 8 V from a level of approximately +2 V.

(b) Disconnect the test oscilloscope.

4.3.14 X Amplifier

(a) Set EXPAND to x1 and X input coupling to EXT DC.

(b) Connect the test constant-amplitude oscillator, frequency set to 50 kHz, to X IN. Set the output of the oscillator to give a display amplitude of 5 cm.

(c) Increase the frequency until the display amplitude has fallen to 3.6 cm. Check that this frequency is greater than 1.9 MHz. Disconnect the test constant-amplifier oscillator.

(d) Set X input coupling to EXT DC.

(e) Connect the voltage output of the test oscilloscope calibrator, output set to 5 V, to X IN. Adjust X SHIFT, if necessary, to obtain two dots approximately 5 cm apart.

(f) Set the test oscilloscope calibrator output to +. Check that the left-hand spot disappears, the right-hand spot remaining visible.

(g) Disconnect the test oscilloscope calibrator and reset X input coupling to INT SWEEP.

4.4 POWER SUPPLY

These checks should be made after the power supply unit has been repaired.

4.4.1 Test Equipment Required

The following test equipment and supplies are required:-

(a) A.C. and d.c. multi-range voltmeter, sensitivity 20000 ohms per volt, calibrated against a sub-standard instrument at 20 V. (A TF 2670 is suitable)

(b) A variac transformer. Input voltage 230 V, 50 Hz; output voltage range 80 V to 270 V, 100 VA.

(c) Electrostatic voltmeter calibrated at 3 kV (or a voltmeter capable of measuring this voltage, the meter current not being greater than 20 μA.)

(d) Stabilised d.c. power supply, output voltage variable between 20 V and 30 V, maximum output current 1.5 A.

4.4.2 Procedure

(a) Ensure that the input voltage selector is set to the 230 V position and that fuse links FS1 (500 mA) and FS2 (2 A) are correctly positioned and in good order.

(b) Connect the oscilloscope to the output of the test variac and connect the variac, output set to minimum, to a 230 V a.c. supply. Increase the variac output to 230 V.

(c) Set BRILL fully counter-clockwise and SUPPLY downwards (on). Check that the SUPPLY lamp glows and allow the oscilloscope five minutes to stabilise.

(d) Connect the test meter, set to the 25 V d.c. range, between TB1-6 (+ve) and TB1-3 or TB1-8 (ground). Adjust 1RV1 to obtain an indication of 20 V $\pm$0.05 V.

(e) Check that the voltage of each supply, with respect to ground (TB1-3 or TB1-8) is within the specified limits (Table 4.3).

Supply line (nominal)	Pin No.	Meter indication and tolerance
+140 V	TB1-9	+140 V ±5 V
+80 V	TB1-7	+80 V ±3 V
+75 V	TB1-2	+75 V ±3 V
+20 V	TB1-6	+20 V ±0.05 V
+9 V	TB1-5	+9.3 V ±0.2 V
-9 V	TB1-4	-9.6 V ±0.2 V
- 40 V	TB1-10	-42 V ±1.5 V

Table 4.3. Power Supply Monitoring

NOTES: 1. Before connecting (or disconnecting) the relevant test meter to the pins detailed in (f), (g) and (h), following, set SUPPLY OFF.

2. X1 pin 27 and pin 28 are at a potential of -1 kV with respect to ground.

(f) Connect the electrostatic voltmeter (or the meter fitted with a shunt), set to the 2.5 kV range, between x1 pin 32 (-ve) and ground. Check that the indication on the meter is 1.04 kV ±50 V.

(g) Connect the test meter, set to the 10 V a.c. range, between x1 pin 27 and pin 28. Check that the indication on the meter is 6.9 V ±0.3 V.

(h) Connect the test meter between pin 31 (+ve) and ground. Check that the indication on the meter is 2.8 kV ±200 V.

(j) Reconnect the test meter, set to the 25 V d.c. range, between TB1-6 (+ve) and TB1-3 or TB1-8 (ground). Adjust the variac to vary the line supply to the oscilloscope between 185 V and 265 V and note any variation in the +20 V supply. This variation should not be greater than 100 mV.

(k) Set SUPPLY to OFF and the variac output to 110 V. Switch the input voltage selector to 115 V and replace fuse link FS1 with a 1 A fuse. Set SUPPLY downwards (on).

(m) Adjust the test variac to vary the line supply between 97 V and 133 V and note any variation in the +20 V supply. This variation should not be greater than 100 mV.

(n) Set SUPPLY to OFF and the variac output to minimum. Disconnect the test variac from the 230 V a.c. supply and the oscilloscope from the variac. Reset the input voltage selector to 230 V and refit FS1 with a 500 mA fuse.

(p) Connect the test d.c. power supply to the battery input SKT H in series with the test meter, set to the 10 A d.c. range. Ensure correct polarity of connection.

(q) Set the supply output to 24 V and set SUPPLY downwards (on). Check that the current is between 0.8 A and 1.4 A. Set SUPPLY to OFF.

(r) Connect the test meter, set to 25 V d.c. range, between TB1-6 (+ve) and TB1-3 or TB1-8 (ground). Set SUPPLY downwards (on) and vary the output of the d.c. supply between 20 V and 30 V. Check that any variation in the +20 V supply is less than 100 mV.

(s) Set SUPPLY to OFF and disconnect the test meter and d.c. supply.

Chapter 5

Repair

5.1 INTRODUCTION

This section contains information for the localization and repair of faults and detailed re-alignment procedures. Performance limits quoted are for guidance only and should not be taken as guaranteed performance specifications unless they are also quoted in the Data Summary section.

In the case of difficulty, please write or phone the Marconi Instruments Service Division (see address on back cover) or nearest representative quoting the type and serial number on the data plate on the rear of the instrument.

If the instrument is being returned for repair, please indicate clearly the nature of the fault and the work you require to be done.

WARNING: Do not remove the cover unless the instrument is disconnected from the a.c. supply (or battery, if d.c. operated).

When the instrument is withdrawn from its case and power applied, access is immediate to dangerous voltages:

(a) 250 V a.c. supply
(b) +3 kV d.c. from 1T1 (c.r.t./p.d.a. voltage).
(c) -1 kV d.c. from 1T1 (c.r.t. cathode voltage).

Wiring Colour Code

All insulated wire and cables used in the oscilloscope are colour-coded to aid circuit tracing. Signal-carrying leads are single-coloured and, with exception of co-axial and twin-feeder leads, are type 7/0076. The low-voltage supply leads, not e.h.t. leads, are single-coloured, with exception of the -40 V line, and are type 14/0076. Table 5.1 gives the wiring colour code for the low-voltage supply leads.

Supply	Colour
+140 V	Brown
+80 V	Red
+75 V	Green
+20 V	Orange
+9 V	Yellow
0 V	Black
-9 V	Slate
-40 V	Red/White

Fig. 5.1. Power Supply Wiring Colour Code

5.2 FAULT LOCATION

The following information is provided to facilitate fault diagnosis of the TF 2204. Reference should be made to other sections of this handbook, in conjunction with this section, to aid in locating the defective component(s): the circuit descriptions, circuit diagrams and component location diagrams are especially helpful in this respect. Reference should be made to Chapter 3.1, for the method of component coding used.

5.2.1 Test Equipment Required

(a) Multimeter A.C. and D.C. The TF 2670 is suitable.

(b) Test oscilloscope. An oscilloscope of specification similar to that of the TF 2204. A probe should be used to reduce circuit loading.

(c) Transistor tester. The TF 2703 is suitable.

5.2.2 Fault Diagnosis Techniques

Before proceeding with the detailed guides to fault location shown in Figs 5.1 to 5.6 inclusive, the following simple checks should be made:-

(a) Control Settings. Ensure that the controls are correctly set: in many cases, non-existent faults are due to incorrect settings.

(b) Calibration. Non-existent faults can also be due to mis-alignment. Refer to section 5.4 of this chapter for detailed calibration procedures.

(c) Fault Location. To isolate a fault to circuit level, note any symptoms. In many cases, the circuit or board in which the fault has occurred can be identified from those symptoms. For example, an unacceptable quality of display (e.g. excess brilliance, poor focus) indicates that the c.r.t. or relevant display controls, or e.h.t. may be faulty. Incorrect operation of many (or all) circuits indicates a fault in the power supply or supply interconnections. Note that a fault on one supply may cause all the outputs of the d.c./d.c. converter to fail. A large overload will cause a protective fuse to rupture.

(d) Overheated components. Failure of a component due to overheating may be a symptom of a fault in an associated circuit. After replacing such a component, check whether overheating and failure re-occurs. If so, determine the cause.

The fault location charts provide guides in locating faults, in many instances down to component level. However, the charts can only cover typical faults and omit faults that are obvious in location (e.g. no difference in display between the x1 and x5 positions of the EXPAND switch indicates that the X-amplifier circuit is faulty).

Fig. 5.1 is a master fault location chart and should be the first to be used. It locates the fault down to board level and onward refers the serviceman to the appropriate fault location chart. However, the location of faults may be immediately obvious from symptoms noted when calibration procedures or performance checks have been made. Direct reference should then be made to the appropriate chart. However, to maintain a logical development on all charts, some duplication of information exists between charts.

NOTE: Renewal of components or repair may necessitate re-calibration of the affected circuits. (refer to chapter 5.4)

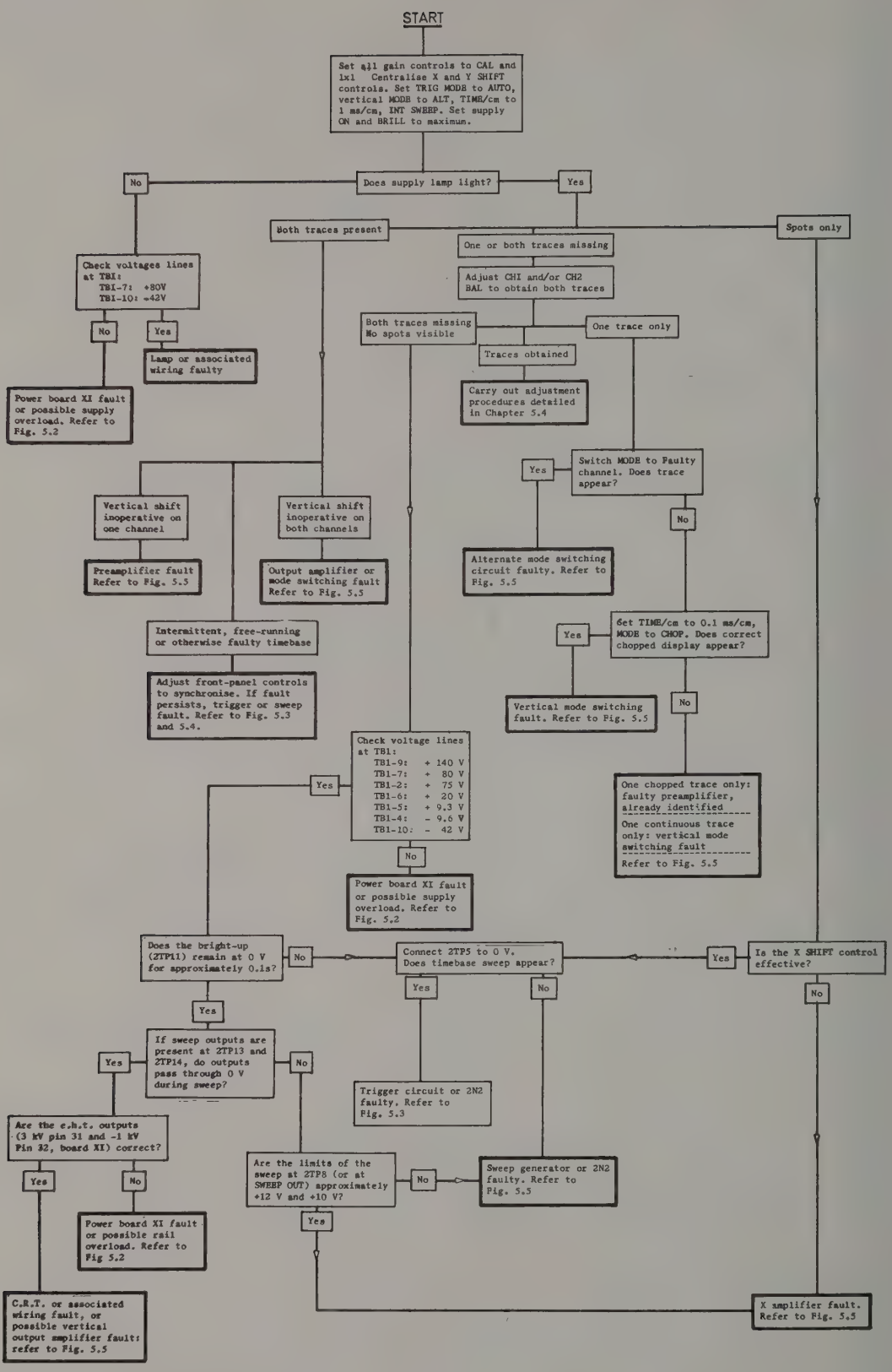

START
Set all gain controls to CAL and 1x1 Centralise X and Y SHIFT controls. Set TRIG MODE to AUTO, vertical MODE to ALT, TIME/cm to 1 ms/cm, INT SWEEP. Set supply ON and BRILL to maximum.
Does supply lamp light?
No
Yes
Check voltages lines at TB1:
TB1-7: +80V
TB1-10: -42V
No
Yes
Lamp or associated wiring faulty
Power board XI fault or possible supply overload. Refer to Fig. 5.2
Both traces present
One or both traces missing
Spots only
Adjust CH1 and/or CH2 BAL to obtain both traces
Both traces missing No spots visible
One trace only
Traces obtained
Carry out adjustment procedures detailed in Chapter 5.4
Yes
Switch MODE to Faulty channel. Does trace appear?
No
Alternate mode switching circuit faulty. Refer to Fig. 5.5
Vertical shift inoperative on one channel
Vertical shift inoperative on both channels
Preamplifier fault Refer to Fig. 5.5
Output amplifier or mode switching fault Refer to Fig. 5.5
Intermittent, free-running or otherwise faulty timebase
Adjust front-panel controls to synchronise. If fault persists, trigger or sweep fault. Refer to Fig. 5.3 and 5.4.
Yes
Set TIME/cm to 0.1 ms/cm, MODE to CHOP. Does correct chopped display appear?
Vertical mode switching fault. Refer to Fig. 5.5
No
One chopped trace only: faulty preamplifier, already identified
One continuous trace only: vertical mode switching fault
Refer to Fig. 5.5
Check voltage lines at TB1:
TB1-9: + 140 V
TB1-7: + 80 V
TB1-2: + 75 V
TB1-6: + 20 V
TB1-5: + 9.3 V
TB1-4: - 9.6 V
TB1-10: - 42 V
Yes
No
Power board XI fault or possible supply overload. Refer to Fig. 5.2
Does the bright-up (ZTP11) remain at 0 V for approximately 0.1s?
No
Connect 2TP5 to 0 V. Does timebase sweep appear?
Yes
Is the X SHIFT control effective?
No
Yes
Yes
No
Yes
If sweep outputs are present at 2TP13 and 2TP14, do outputs pass through 0 V during sweep?
No
Trigger circuit or 2N2 faulty. Refer to Fig. 5.3
Are the e.h.t. outputs (3 kV pin 31 and -1 kV Pin 32, board XI) correct?
Yes
No
Are the limits of the sweep at 2TP8 (or at SWEEP OUT) approximately +12 V and +10 V?
No
Sweep generator or 2N2 faulty. Refer to Fig. 5.5
Yes
Power board XI fault or possible rail overload. Refer to Fig 5.2
C.R.T. or associated wiring fault, or possible vertical output amplifier fault: refer to Fig. 5.5
X amplifier fault. Refer to Fig. 5.5

Fig. 5.1 Master Troubleshooting Chart

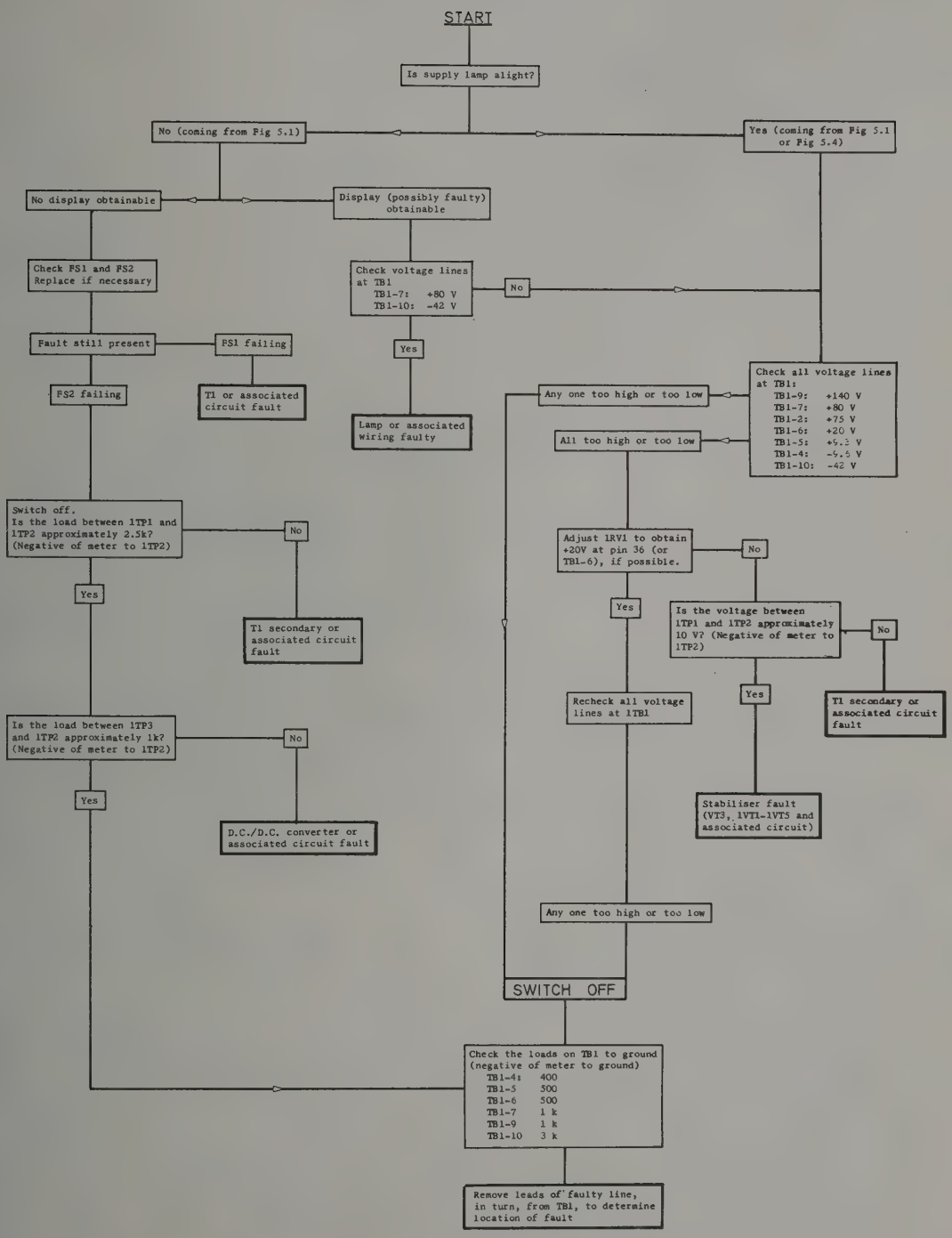

START
Is supply lamp alight?
No (coming from Fig 5.1)
Yes (coming from Fig 5.1 or Fig 5.4)
No display obtainable
Display (possibly faulty) obtainable
Check FS1 and FS2 Replace if necessary
Check voltage lines at TB1
TB1-7: +80 V
TB1-10: -42 V
No
Fault still present
FS1 failing
Yes
FS2 failing
T1 or associated circuit fault
Lamp or associated wiring faulty
Check all voltage lines at TB1:
TB1-9: +140 V
TB1-7: +80 V
TB1-2: +75 V
TB1-6: +20 V
TB1-5: +5.3 V
TB1-4: -5.5 V
TB1-10: -42 V
Any one too high or too low
All too high or too low
Switch off.
Is the load between 1TP1 and 1TP2 approximately 2.5k? (Negative of meter to 1TP2)
No
Yes
T1 secondary or associated circuit fault
Adjust 1RV1 to obtain +20V at pin 36 (or TB1-6), if possible.
No
Yes
Is the voltage between 1TP1 and 1TP2 approximately 10 V? (Negative of meter to 1TP2)
No
Yes
T1 secondary or associated circuit fault
Recheck all voltage lines at 1TB1
Stabiliser fault (VT3, 1VT1-1VT5 and associated circuit)
Is the load between 1TP3 and 1TP2 approximately 1k? (Negative of meter to 1TP2)
No
Yes
D.C./D.C. converter or associated circuit fault
Any one too high or too low
SWITCH OFF
Check the loads on TB1 to ground (negative of meter to ground)
TB1-4: 400
TB1-5 500
TB1-6 500
TB1-7 1 k
TB1-9 1 k
TB1-10 3 k
Remove leads of faulty line, in turn, from TB1, to determine location of fault

Fig. 5.2 Power Supply Unit X1 - Troubleshooting Chart

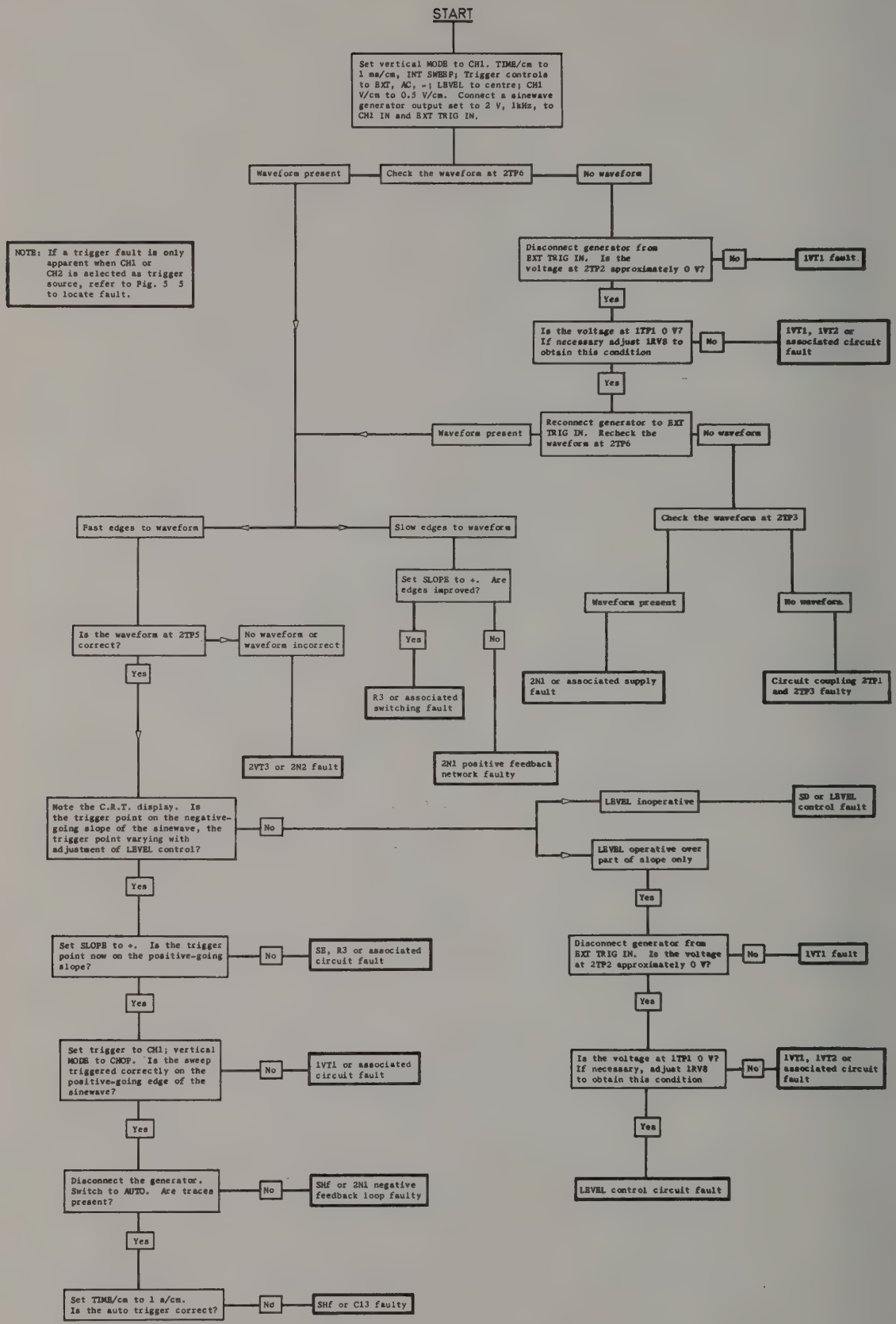

START
Set vertical MODE to CH1. TIME/cm to 1 ms/cm, INT SWEEP; Trigger controls to EXT, AC, -; LEVEL to centre; CH1 V/cm to 0.5 V/cm. Connect a sinewave generator output set to 2 V, 1kHz, to CH1 IN and EXT TRIG IN.
Waveform present
Check the waveform at 2TP6
No waveform
NOTE: If a trigger fault is only apparent when CH1 or CH2 is selected as trigger source, refer to Fig. 5 5 to locate fault.
Disconnect generator from EXT TRIG IN. Is the voltage at 2TP2 approximately 0 V?
No
1VT1 fault
Yes
Is the voltage at 1TP1 0 V? If necessary adjust 1RV8 to obtain this condition
No
1VT1, 1VT2 or associated circuit fault
Yes
Waveform present
Reconnect generator to EXT TRIG IN. Recheck the waveform at 2TP6
No waveform
Fast edges to waveform
Slow edges to waveform
Check the waveform at 2TP3
Set SLOPE to +. Are edges improved?
Waveform present
No waveform
Is the waveform at 2TP5 correct?
No waveform or waveform incorrect
Yes
No
2N1 or associated supply fault
Circuit coupling 2TP1 and 2TP3 faulty
Yes
R3 or associated switching fault
2VT3 or 2N2 fault
2N1 positive feedback network faulty
Note the C.R.T. display. Is the trigger point on the negative-going slope of the sinewave, the trigger point varying with adjustment of LEVEL control?
No
LEVEL inoperative
SD or LEVEL control fault
LEVEL operative over part of slope only
Yes
Yes
Set SLOPE to +. Is the trigger point now on the positive-going slope?
No
SE, R3 or associated circuit fault
Disconnect generator from EXT TRIG IN. Is the voltage at 2TP2 approximately 0 V?
No
1VT1 fault
Yes
Yes
Set trigger to CH1; vertical MODE to CHOP. Is the sweep triggered correctly on the positive-going edge of the sinewave?
No
1VT1 or associated circuit fault
Is the voltage at 1TP1 0 V? If necessary, adjust 1RV8 to obtain this condition
No
1VT1, 1VT2 or associated circuit fault
Yes
Yes
Disconnect the generator. Switch to AUTO. Are traces present?
No
SHf or 2N1 negative feedback loop faulty
LEVEL control circuit fault
Yes
Set TIME/cm to 1 s/cm. Is the auto trigger correct?
No
SHf or C13 faulty

Fig. 5.3 Trigger Generator X2 - Troubleshooting Chart

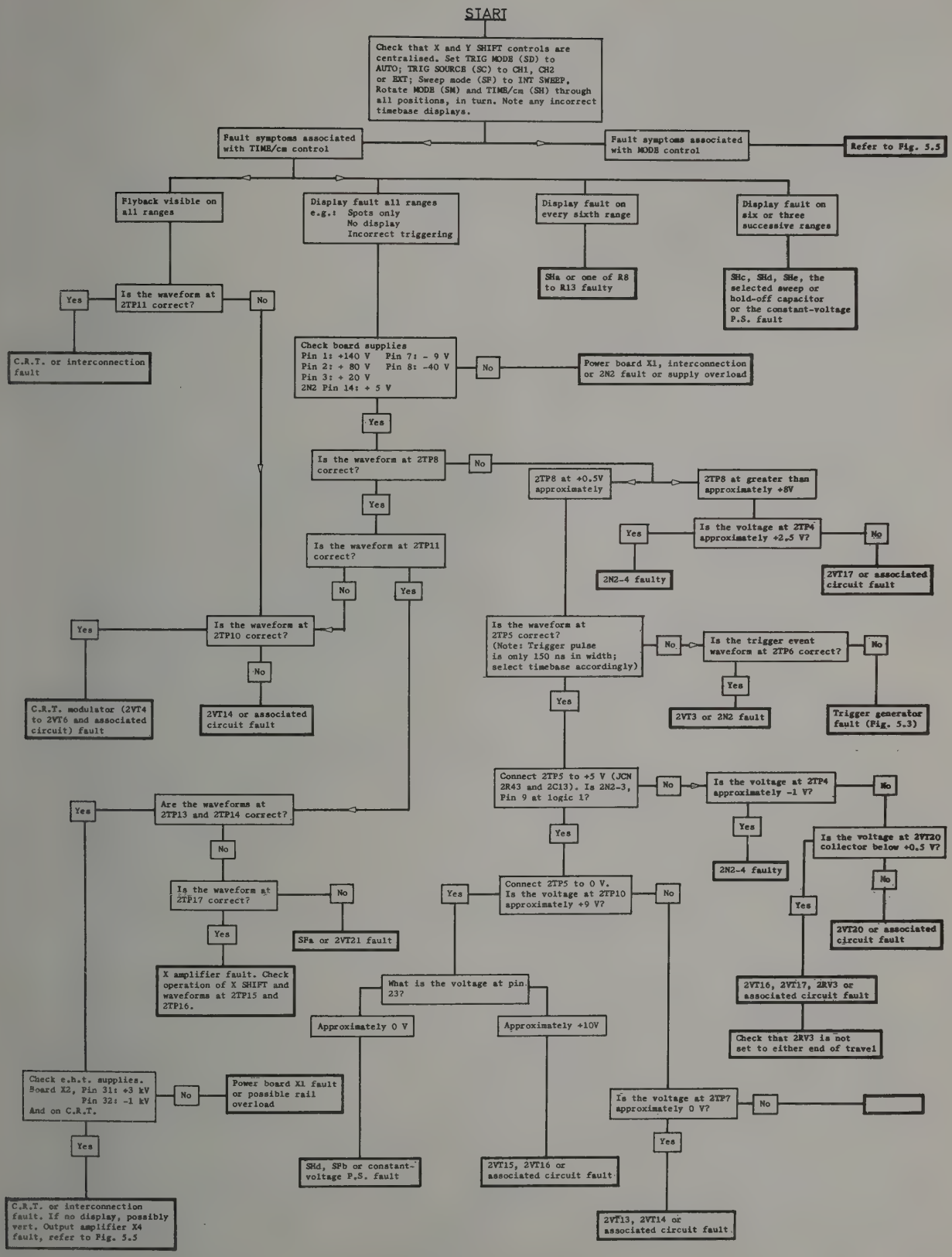

START
Check that X and Y SHIFT controls are centralised. Set TRIG MODE (SD) to AUTO; TRIG SOURCE (SC) to CH1, CH2 or EXT; Sweep mode (SF) to INT SWEEP. Rotate MODE (SM) and TIME/cm (SH) through all positions, in turn. Note any incorrect timebase displays.
Fault symptoms associated with TIME/cm control
Fault symptoms associated with MODE control
Refer to Fig. 5.5
Flyback visible on all ranges
Display fault all ranges e.g.: Spots only No display Incorrect triggering
Display fault on every sixth range
Display fault on six or three successive ranges
SHa or one of R8 to R13 faulty
SHc, SHd, SHe, the selected sweep or hold-off capacitor or the constant-voltage P.S. fault
Yes
Is the waveform at 2TP11 correct?
No
C.R.T. or interconnection fault
Check board supplies Pin 1: +140 V Pin 7: - 9 V Pin 2: + 80 V Pin 8: -40 V Pin 3: + 20 V 2N2 Pin 14: + 5 V
No
Power board X1, interconnection or 2N2 fault or supply overload
Yes
Is the waveform at 2TP8 correct?
No
2TP8 at +0.5V approximately
2TP8 at greater than approximately +8V
Yes
Is the voltage at 2TP4 approximately +2.5 V?
No
2N2-4 faulty
2VT17 or associated circuit fault
Yes
Is the waveform at 2TP11 correct?
No
Yes
Yes
Is the waveform at 2TP10 correct?
No
C.R.T. modulator (2VT4 to 2VT6 and associated circuit) fault
2VT14 or associated circuit fault
Is the waveform at 2TP5 correct? (Note: Trigger pulse is only 150 ns in width; select timebase accordingly)
No
Is the trigger event waveform at 2TP6 correct?
No
Yes
2VT3 or 2N2 fault
Trigger generator fault (Fig. 5.3)
Yes
Connect 2TP5 to +5 V (JCN 2R43 and 2C13). Is 2N2-3, Pin 9 at logic 1?
No
Is the voltage at 2TP4 approximately -1 V?
No
Yes
2N2-4 faulty
Is the voltage at 2VT20 collector below +0.5 V?
No
Yes
2VT20 or associated circuit fault
Yes
Are the waveforms at 2TP13 and 2TP14 correct?
No
Is the waveform at 2TP17 correct?
No
Yes
SFa or 2VT21 fault
X amplifier fault. Check operation of X SHIFT and waveforms at 2TP15 and 2TP16.
Yes
Connect 2TP5 to 0 V. Is the voltage at 2TP10 approximately +9 V?
No
2VT16, 2VT17, 2RV3 or associated circuit fault
Check that 2RV3 is not set to either end of travel
What is the voltage at pin 23?
Approximately 0 V
Approximately +10V
SHd, SFb or constant-voltage P.S. fault
2VT15, 2VT16 or associated circuit fault
Check e.h.t. supplies. Board X2, Pin 31: +3 kV Pin 32: -1 kV And on C.R.T.
No
Power board X1 fault or possible rail overload
Yes
C.R.T. or interconnection fault. If no display, possibly vert. Output amplifier X4 fault, refer to Fig. 5.5
Is the voltage at 2TP7 approximately 0 V?
No
Yes
2VT13, 2VT14 or associated circuit fault

Fig. 5.4 Sweep Generator and X Amplifier X2 - Troubleshooting Chart

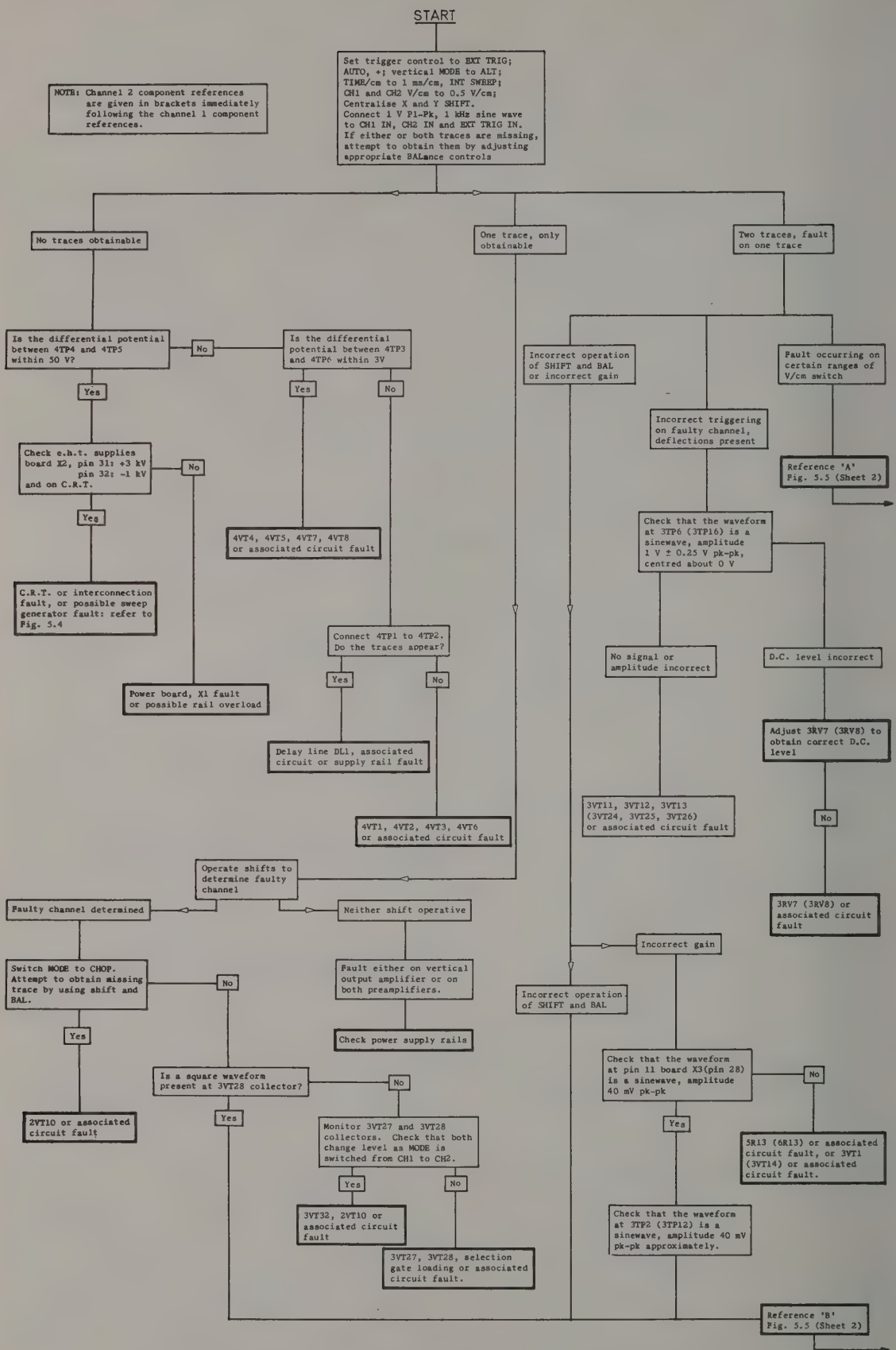

START
Set trigger control to EXT TRIG; AUTO, +; vertical MODE to ALT; TIME/cm to 1 ms/cm, INT SWEEP; CH1 and CH2 V/cm to 0.5 V/cm; Centralise X and Y SHIFT. Connect 1 V P1-Pk, 1 kHz sine wave to CH1 IN, CH2 IN and EXT TRIG IN. If either or both traces are missing, attempt to obtain them by adjusting appropriate BALance controls
NOTE: Channel 2 component references are given in brackets immediately following the channel 1 component references.
No traces obtainable
One trace, only obtainable
Two traces, fault on one trace
Is the differential potential between 4TP4 and 4TP5 within 50 V?
No
Is the differential potential between 4TP3 and 4TP6 within 3V
Yes
Yes
No
Check e.h.t. supplies board X2, pin 31: +3 kV pin 32: -1 kV and on C.R.T.
No
Yes
4VT4, 4VT5, 4VT7, 4VT8 or associated circuit fault
C.R.T. or interconnection fault, or possible sweep generator fault: refer to Fig. 5.4
Connect 4TP1 to 4TP2. Do the traces appear?
Yes
No
Power board, X1 fault or possible rail overload
Delay line DL1, associated circuit or supply rail fault
4VT1, 4VT2, 4VT3, 4VT6 or associated circuit fault
Operate shifts to determine faulty channel
Faulty channel determined
Neither shift operative
Switch MODE to CHOP. Attempt to obtain missing trace by using shift and BAL.
No
Yes
Fault either on vertical output amplifier or on both preamplifiers.
Check power supply rails
Is a square waveform present at 3VT28 collector?
No
Yes
2VT10 or associated circuit fault
Monitor 3VT27 and 3VT28 collectors. Check that both change level as MODE is switched from CH1 to CH2.
Yes
No
3VT32, 2VT10 or associated circuit fault
3VT27, 3VT28, selection gate loading or associated circuit fault.
Incorrect operation of SHIFT and BAL or incorrect gain
Fault occurring on certain ranges of V/cm switch
Incorrect triggering on faulty channel, deflections present
Reference 'A' Fig. 5.5 (Sheet 2)
Check that the waveform at 3TP6 (3TP16) is a sinewave, amplitude 1 V ± 0.25 V pk-pk, centred about 0 V
No signal or amplitude incorrect
D.C. level incorrect
Adjust 3RV7 (3RV8) to obtain correct D.C. level
3VT11, 3VT12, 3VT13 (3VT24, 3VT25, 3VT26) or associated circuit fault
No
3RV7 (3RV8) or associated circuit fault
Incorrect gain
Incorrect operation of SHIFT and BAL
Check that the waveform at pin 11 board X3(pin 28) is a sinewave, amplitude 40 mV pk-pk
No
Yes
5R13 (6R13) or associated circuit fault, or 3VT1 (3VT14) or associated circuit fault.
Check that the waveform at 3TP2 (3TP12) is a sinewave, amplitude 40 mV pk-pk approximately.
Reference 'B' Fig. 5.5 (Sheet 2)

Fig. 5.5 Vertical Deflection System (Sheet 1) Troubleshooting Chart

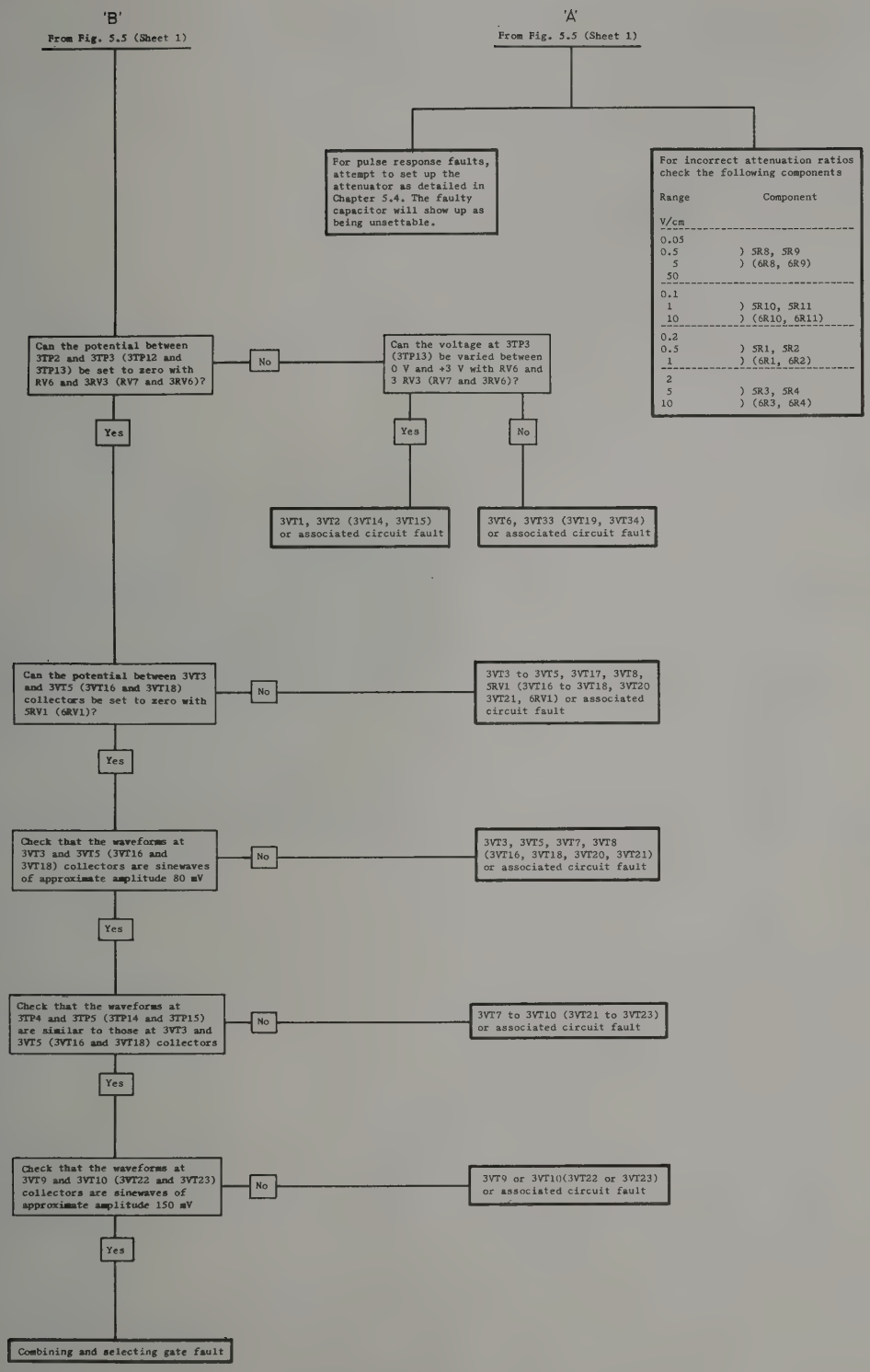

'B'
From Fig. 5.5 (Sheet 1)
'A'
From Fig. 5.5 (Sheet 1)
For pulse response faults, attempt to set up the attenuator as detailed in Chapter 5.4. The faulty capacitor will show up as being unsettable.
For incorrect attenuation ratios check the following components
Range
Component
V/cm
0.05
0.5) 5R8, 5R9
5) (6R8, 6R9)
50
0.1
1) 5R10, 5R11
10) (6R10, 6R11)
0.2
0.5) 5R1, 5R2
1) (6R1, 6R2)
2
5) 5R3, 5R4
10) (6R3, 6R4)
Can the potential between 3TP2 and 3TP3 (3TP12 and 3TP13) be set to zero with RV6 and 3RV3 (RV7 and 3RV6)?
No
Can the voltage at 3TP3 (3TP13) be varied between 0 V and +3 V with RV6 and 3 RV3 (RV7 and 3RV6)?
Yes
Yes
No
3VT1, 3VT2 (3VT14, 3VT15) or associated circuit fault
3VT6, 3VT33 (3VT19, 3VT34) or associated circuit fault
Yes
Can the potential between 3VT3 and 3VT5 (3VT16 and 3VT18) collectors be set to zero with 5RV1 (6RV1)?
No
3VT3 to 3VT5, 3VT17, 3VT8, 5RV1 (3VT16 to 3VT18, 3VT20 3VT21, 6RV1) or associated circuit fault
Yes
Check that the waveforms at 3VT3 and 3VT5 (3VT16 and 3VT18) collectors are sinewaves of approximate amplitude 80 mV
No
3VT3, 3VT5, 3VT7, 3VT8 (3VT16, 3VT18, 3VT20, 3VT21) or associated circuit fault
Yes
Check that the waveforms at 3TP4 and 3TP5 (3TP14 and 3TP15) are similar to those at 3VT3 and 3VT5 (3VT16 and 3VT18) collectors
No
3VT7 to 3VT10 (3VT21 to 3VT23) or associated circuit fault
Yes
Check that the waveforms at 3VT9 and 3VT10 (3VT22 and 3VT23) collectors are sinewaves of approximate amplitude 150 mV
No
3VT9 or 3VT10(3VT22 or 3VT23) or associated circuit fault
Yes
Combining and selecting gate fault

Fig. 5.5 Vertical Deflection System (Sheet 2) Troubleshooting Chart

5.3 RENEWAL OF SUB-ASSEMBLIES

Soldering Techniques

Standard techniques of component renewal should be used but care must be taken to prevent excess heat from damaging the circuit board otherwise the printed wiring may lift away from the base material. When cleaning the area around a solder connection with a flux-remover solvent, be careful not to remove information printed on the board. All solder connections to components associated with either e.h.t. supply should have smooth surfaces. Any protrusions may cause high-voltage arcing in low-pressure or high-humidity environments. A vacuum-type desoldering tool is recommended for removing excess solder.

5.3.1 Board Sub-assemblies

Viewed from the front of the equipment, the board sub-assemblies are mounted as follows:-

(a) X3, vertical amplifier. Mounted vertically on the right-hand side at the centre of the instrument. The board is hinged and can be released to gain access to components located behind it. To release the board remove the two 4-40 UNC screws that secure the support tie bar to the main-frame tie bars and the two 4-40 UNC screws that secure the board to the two ground brackets (points 6A and 6B): the board is then free to swing outwards, limited by stops on the main-frame tie bars.

(b) X4, vertical output amplifier. Mounted on the central bulkhead, at the rear of the instrument. Each side of the board is accessible, although servicing can be facilitated by swinging out board X3 and removing the four 4-40 UNC screws that secure board X4 to the central bulkhead.

(c) X2, trigger, sweep generator and X amplifier. Mounted horizontally on the left-hand side of the instrument below the c.r.t. The board is hinged and can be released to give access to the power unit. To release the board remove the 6-32 UNC screw securing the lower left-hand tie bar to the rear panel and the 4-40 UNC screw securing the tie bar to the tie-bar coupling near the front panel: the board is then free to swing outwards, limited by stops on the central bulkhead.

(d) X1 power unit. Mounted on the central bulkhead, protected by an aluminium cover, behind the trigger, sweep generator and X amplifier board. The board is hinged and can be released to give access to the power-supply circuit components mounted on the rear panel. To release the board, firstly release board X2, then remove the four screws that secure the protective cover and unscrew the knurled thumbscrew located on the side edge of the board: the board is then free to swing outwards.

5.3.2 Controls

The controls are easily accessible, although additional access can be gained to the timebase controls by swinging out board X2, and to the vertical mode switch by swinging out board X3.

5.3.3 C.R.T. Replacement

(a) Remove the c.r.t. base protective cover from the rear panel (four 4-40 UNC screws).

(b) Remove the bezel from the front panel (two 6-32 UNC screws).

(c) Remove the c.r.t. valve-base and disconnect the p.d.a. connection.

(d) Place the instrument front panel downwards on a soft rubber pad or similar.

(e) Press firmly on the base of the c.r.t. taking care to avoid bending the pins or breaking the vacuum-seal pip, until the c.r.t. moves smoothly out of the instrument (approximately one inch).

(f) Place the instrument upright and ease the c.r.t. away from the instrument.

(g) Refit the c.r.t. by carrying out the reverse of the removal procedure, ensuring that the graticule is aligned with the front-panel sides.

5.3.4 C.R.T. Assembly Replacement

(a) Remove the c.r.t. base protective cover from the rear panel (four 4-40 UNC screws).

(b) Remove the bezel from the front panel (two 6-32 UNC screws).

(c) Release the c.r.t. front panel clamp (four 6-32 UNC screws).

(d) Remove the c.r.t. base, disconnect the p.d.a. connection, and unsolder the two trace-rotate leads from the c.r.t. noting the positions to which the leads were connected.

(e) Swing out board X2 and remove the cover from board X1.

(f) Remove the two self-tapping screws securing each of the two c.r.t. shield supports to the bulkhead. (Note that three of these screws are used to secure cableform cleats).

(g) Lift the rear of the c.r.t. assembly approximately $\frac{1}{2}$ in. upwards and ease it approximately 2 in. towards the rear panel. Then lift the assembly outwards and upwards clear of the main frame.

NOTE: Handle the c.r.t. assembly with care. Knocking, jarring or distortion of the shield will destroy its magnetic properties.

(h) Refit the c.r.t. assembly by carrying out the reverse of the removal procedure.

5.3.5 Attenuator X5 and X6 Replacement

(a) Remove the knobs from the V/cm/SHIFT and V/cm FINE/GAIN controls on the appropriate attenuator.

(b) Unsolder the input signal lead (white) from the barb tag at the front of the attenuator.

(c) Undersolder the leads from the BAL, CAL, SET, SHIFT, V/cm FINE and GAIN controls, ground tags and barb tags on the rear of the attenuator, noting the destinations of the leads.

(d) Swing out board x3.

(e) Remove the support strut from the rear of the attenuators. This is secured by three 4-40 UNC screws, one on each attenuator and one on the PULL TO INVERT switch bracket.

(f) If removing attenuator x5 (CH1), remove the support bracket from the bulkhead and attenuator (two 4-40 UNC screws).

(g) Release the hinge brackets of board X3 from the tie bars (one 4-40 UNC screw and one 4-40 UNC stop screw on each bracket).

(h) Ease board X3 outwards and backwards to the extent of the cableform.

(j) The appropriate attenuator can then be eased out of the instrument.

(k) Refit the attenuator by carrying out the reverse of the removal procedure.

5.3.6 Power Transistors VT1 to VT3 Replacement

The case (collector) of each of these transistors (mounted on the rear panel) is insulated from the chassis by a mica washer and insulating bushes. An insulating cover fitted over each transistor provides further insulation from ground. When replacing one of these transistors, check the collector/chassis resistance with the multimeter before connecting the emitter and base leads. In addition, fit insulating sleeving over the emitter and base pins.

5.3.7 Power Transformer T1 Replacement

Remove the power transformer complete with all components mounted on it, having first disconnected the leads from the cableform. Transfer the components on the old transformer onto the new one before fitting it to the instrument.

5.4 RE-CALIBRATION PROCEDURE

The procedures in this section refer to the adjustment of internal or front-panel preset controls. Control settings and test equipment connections should not be changed except as instructed. Details of periodic performance checks are to be found in Chapter 4.

Where procedures are identical for channels 1 and 2, channel 2 component references (for control annotations, etc.,) are quoted in brackets, immediately following the channel 1 component references.

Reference should be made to (Chapter 3.1), for the system of component coding used in this manual.

5.4.1 Test Equipment Required

The following test equipment is required:

(a) A.C. and d.c. multi-range voltmeter, sensitivity 20 000 ohms per volt, calibrated against a sub-standard instrument at 20 V (An AVO Model 8SX or TF2670 is suitable).

(b) Oscilloscope, general purpose. Specification similar to that of the TF 2204.

(c) An oscilloscope calibrator. (A Bradley 156 is suitable). Set voltage output to square wave (1 kHz).

(d) Two constant amplitude sinewave generators. Frequency variable between 1 kHz and 50 kHz and output variable between 0 V and 10 V when loaded with 1 MΩ. (A TF 1370A is suitable).

(e) Capacitance standardiser. 35 pF shunted by 1 MΩ $\pm$1% BNC socket.

(f) A fast pulse generator providing pulses with a rise time better than 4 ns, pulse top flat to within 1% and overshoot less than 2%.

(g) Termination pad (50 ohms resistance pad).

5.4.2 Preliminary Settings

(a) Remove the cover from the instrument (eight 6-32 UNC screws on rear panel), and the protective cover from the power unit board.

(b) Ensure that the input voltage selector is set to the 230 V position and that fuse links FS1 (500 mA) and FS2 (2A) are correctly positioned and in good order.

(c) Connect the oscilloscope to a 230 V a.c. supply.

(d) Set (i) BRILL fully counter-clockwise
(ii) TRIG MODE to AUTO; TRIG SOURCE TO CH1; slope to +
(iii) TIME/cm to 0.1 ms/cm; TIME/cm VAR to CAL; EXPAND to x1; INT SWEEP
(iv) MODE to CH1
(v) CH1 V/cm to 0.5 V/cm; V/cm FINE to CAL; GAIN to x1; AC
(vi) CH2 V/cm to 0.02 V/cm; V/cm FINE to CAL; GAIN to x1; GND
(vii) PULL TO INVERT pushed in

(e) Set SUPPLY downwards (on). Check that the SUPPLY lamp glows and allow the oscilloscope five minutes to stabilise.

5.4.3 Power Supplies

(a) Connect the test meter, set to the 25 V d.c. range, between pin 6 (+ve) and pin 3 or pin 8 (ground-chassis) on TB1.

(b) Adjust 1RV1 to obtain an indication of 20 V $\pm$0.05V.

5.4.4 C.R.T. Geometry

(a) Connect the test constant-amplitude sinewave generator, frequency set to 50 kHz, output approximately 2 V p-p., to CH1 IN.

(b) Advance BRILL until the intensity of the trace is adequate and adjust FOCUS and ASTIG to obtain a well-defined trace.

NOTES: 1. To increase the life of the c.r.t. do not turn BRILL higher than necessary for a satisfactory display.

2. To check for correct setting of the ASTIG control, slowly turn FOCUS through the optimum setting. If the ASTIG adjustment is correct, the horizontal and vertical portions of the channel 1 trace will come into sharpest focus at one position of the FOCUS control. The setting of the ASTIG control should then be correct for any display.

(c) Adjust the CH1 SHIFT to position the display about the central horizontal graticule line. If necessary, adjust TRACE ROTATE to set the display parallel with the horizontal graticule lines.

(d) Set the OUTPUT of the test sinewave generator to produce a display of 8 cm amplitude.

(e) Connect the other test sinewave generator, frequency set to 1 kHz to X IN. Set X input coupling to EXT AC. Set the output of the sinewave generator to produce a display of width 10 cm. Adjust X SHIFT as necessary.

(f) Adjust geometry adjust, 2RV9, so that the raster is as near rectangular as possible. Ensure that each horizontal edge lies within a pair of imaginary lines 1.0 mm apart drawn along the edges of the graticule, and each vertical edge lies within a pair of imaginary lines 1.25 mm apart drawn along the edges of the graticule.

NOTE: As 2RV9 is adjusted, the sensitivity of the c.r.t. will alter. The output of the signal generators will therefore require resetting during this adjustment procedure.

(g) Disconnect the signal generators and reset input coupling to INT SWEEP.

5.4.5 C.R.T. Modulation

(a) Set sweep input coupling to EXT AC.

(b) Connect the test meter between 2TP11 (+ve) and a convenient 0 V point (-ve).

(c) Adjust 2RV1 to obtain an indication of +9 V ±2 V.

(d) Disconnect the test meter and reset sweep input coupling to INT SWEEP.

5.4.6 Channel 1 (Channel 2) Gain

D.C. Conditions

(a) Set (i) MODE to CH1 (CH2)
(ii) SHIFT, 5RV1 (6RV1), to centre of travel.
(iii) V/cm, 5SA (6SA), to 0.02 V/cm; V/cm FINE, RV8 (RV10), to CAL; GAIN, SJ(SK) to x1; GND.
(iv) BAL, RV6 (RV7), to centre of travel.

(b) Connect the test meter, set to the 25 V D.C. range, between 4TP4 and 4TP5. Adjust coarse balance, 3RV3 (3RV6) for an indication on the meter of 0 V ±10 V. Disconnect the meter.

(c) Adjust BAL, RV6 (RV7), so that on switching GAIN, SJ(SK) between the x1 and x10 positions any vertical movement of the trace is less than 2 mm.

(d) If necessary, adjust SHIFT, 5RV1 (6RV1), to position the trace on the central horizontal graticule.

(e) Connect the test meter, set to the 2.5 V D.C. range, between 3TP6 (3TP16) and 0V. Adjust trigger centre, 3RV7 (3RV8), for an indication on the meter of 0V.

X1 Gain

(a) Set (i) CH1 (CH2) input coupling to AC.
(ii) TIME/cm to 1 ms/cm; TIME/cm VAR to CAL; EXPAND TO x1.

(b) Connect the voltage output of the test oscilloscope calibrator, output amplitude 120 mV, to CH1 IN (CH2 IN).

(c) Centralise the display (this may or may not be synchronised) with SHIFT, 5RV1 (6RV1), if necessary. Set the amplitude of the display to 6 cm with SET CAL, RV9 (RV11).

X10 Gain

(a) Reduce the output of the test oscilloscope calibrator to 12 mV p-p.

(b) Set GAIN, SJ(SK), to x10 and set the amplitude of the display to 6 cm with set x10 gain, 3RV2 (3RV5).

(c) Reset GAIN, SJ(SK), to x1 and disconnect the test oscilloscope calibrator.

Set Leakage

(a) Set (i) MODE to CH1 (CH2)
(ii) CH1 (CH2) input coupling to GND.
(iii) SHIFT, 5RV1 (6RV1), to centralise trace on screen.

(b) Note any change in the vertical position of the trace when the input coupling is switched from GND to DC. Adjust set leakage, 3RV1 (3RV4), to reduce the change to less than 0.5 mm.

5.4.7 Trigger

(a) Set (i) TRIG SOURCE to EXT.
(ii) TRIG MODE to AUTO.

(b) Connect the test meter, set to the 2.5 V D.C. range, between 2TP1 and 0 V. Adjust external trigger centre, 2RV8 for an indication on the meter of 0 V ±0.2 V.

NOTE: It may be necessary to connect 2LK1 across 2D12 or, if already connected, remove 2LK1 from 2D12 to achieve this condition.

5.4.8 Horizontal Deflection System

X1 Gain and Sweep Length

(a) Set (i) MODE to CH1.
(ii) CH1 V/cm FINE to CAL; GAIN to x1; AC.
(iii) TRIG MODE to AC; SLOPE to +; TRIG SOURCE to CH1.
(iv) TIME/cm to 1 ms/cm; TIME/cm VAR to CAL; EXPAND to x1.

(b) Connect the time output of the test oscilloscope calibrator, output period 1 ms, to CH1 IN. Set CH1 V/cm for a display amplitude of approximately 2 cm. If necessary, adjust LEVEL to obtain a stable display.

(c) Position the first marker (start of trace) on the left-hand vertical graticule line with X SHIFT. Adjust set x1, gain 2RV5, so that the markers are 1 cm apart and the second and tenth are aligned with the first and ninth vertical graticule lines from the left.

(d) Position the second marker on the left-hand vertical graticule with X SHIFT. Adjust set trace length, 2RV3, so that the trace just extends to the right-hand vertical graticule line (i.e. over-all trace length of 11 cm).

X5 Gain

(a) Set EXPAND to x5 and position the first marker on the left-hand vertical graticule line with X SHIFT. Adjust set x5 gain, 2RV7, so that the markers are 5 cm apart, i.e. the second and third align with the centre and right-hand vertical graticule lines, respectively.

(b) Reset EXPAND to x1.

Sweep Calibration

(a) Set (i) TIME/cm to 20 ms/cm.
(ii) Oscilloscope calibrator output period to 20 ms.

(b) If necessary position the first marker (start of trace) on the left-hand vertical graticule line with X SHIFT. Adjust set sweep control, 2RV4, so that the markers occur one per centimetre.

(c) Set (i) TIME/cm to 0.1 ms/cm.
(ii) Oscilloscope calibrator output period to 0.1 ms.

(d) If necessary, position the first marker (start of trace) on the left-hand vertical graticule line with X SHIFT. Adjust set sweep control, 2RV6, so that the markers occur one per centimetre.

(e) Set (i) TIME/cm to 0.5 μs/cm
(ii) Oscilloscope calibrator output period to 0.5 μs.

(f) If necessary, position the first marker (start of trace) on the left-hand vertical graticule line with X SHIFT. Adjust set sweep control, 2RV5, so that the markers occur one per centimetre.

(g) Disconnect the test oscilloscope calibrator.

NOTE: On the faster sweep ranges it may become necessary to adjust HF SYNC to obtain a stable display.

5.4.9 Calibrator

(a) Set (i) TIME/cm to 0.1 ms/cm; TIME/cm VAR to CAL; EXPAND to x1.
(ii) MODE to ALT.
(iii) TRIG MODE to AUTO; TRIG SOURCE to CH1; SLOPE +.
(iv) CH2 V/cm to 0.05 V/cm.
(v) CH1 and CH2 V/cm FINE to CAL; GAIN to x1; AC.

(b) Connect the test oscilloscope calibrator, output period 1 ms (1 kHz), to CH1 IN. Set CH1 V/cm for display amplitude approximately 2 cm. If necessary adjust LEVEL for a stable display.

(c) Connect 100 mV 1 kHz calibrator output to CH2 IN.

(d) Adjust 2RV2 so that the drift rate of the CH2 trace is less than one cycle per second, i.e. the time for a pulse on the CH2 trace to drift between any two markers on the CH1 trace is less than one second.

(e) Disconnect the test oscilloscope calibrator and the 100 mV 1 kHz calibrator output.

5.4.10 Channel 1 (Channel 2) Response

Input Capacitance

(a) Set (i) TIME/cm to 1 ms/cm; TIME/cm VAR to CAL; EXPAND to x1.
(ii) MODE to CH1 (CH2).
(iii) V/cm to 0.02 V/cm; V/cm FINE to CAL; GAIN to x1; AC
(iv) TRIG MODE to AUTO; TRIG SOURCE to CH1 (CH2); SLOPE +.

(b) Connect the voltage output of the test oscilloscope calibrator output amplitude 250 mV p-p, via the (35 pF) capacitance standardiser to CH1 IN (CH2 IN).

(c) Adjust 3C1 (3C15) so that any undershoot or overshoot on the displayed waveform is less than 1%.

Attenuator Settings

(a) Reconnect the test oscilloscope calibrator, output amplitude set to 250 mV, directly to CH1 IN (CH2 IN). Set V/cm to 0.05 V/cm.

(b) Check that the amplitude of the displayed waveform is 5 cm $\pm$1 mm and adjust 5C15 (6C15) so that any undershoot or overshoot on the waveform is less than 1%.

(c) Repeat this adjustment for the appropriate capacitor selected by the V/cm switch as detailed in Table 5.2 resetting the output of the oscilloscope calibrator as indicated.

V/cm setting 5SA (6SA)	Oscilloscope calibrator output	Channel 1 adjust	Channel 2 adjust
0.1	250 mV	5C18	6C18
0.2	500 mV	5C3	6C3
0.5	1 V	5C13	6C13
1	5 V	5C16	6C16
2	10 V	5C7	6C7
20	100 V	5C11	6C11

Table 5.2 Attenuator Compensation

(d) Reconnect the capacitance standardiser between the oscilloscope calibrator and CH1 IN (CH2 IN).

(e) Set the V/cm switch and the output of the oscilloscope calibrator as detailed in Table 5.3 and adjust the appropriate capacitor so that any undershoot or overshoot on the displayed waveform is less than 1%. Adjust SHIFT, 5RV1 (6RV1) as necessary.

V/cm setting 5SA (6SA)	Oscilloscope calibrator output	Channel 1 adjust	Channel 2 adjust
0.2	2 V	5C2	6C2
2	20 V	5C6	6C6
20	200 V	5C10	6C10

Table 5.3 Attenuator Input Capacity

(f) Disconnect the capacitance standardiser and oscilloscope calibrator.

Pulse Response

(a) Set (i) V/cm to 0.02 V/cm; V/cm FINE to CAL; GAIN to x1; AC
(ii) MODE to CH1 (CH2).
(iii) TIME/cm to 2 μs/cm; TIME/cm VAR to CAL; EXPAND to x1.
(iv) TRIG MODE to AC; SLOPE to +; TRIG SOURCE to CH1 (CH2).

(b) Connect the positive edge output of the fast pulse generator p.r.f. set to 100 kHz, via termination pad, to CH1 IN (CH2 IN).

(c) Adjust LEVEL, the generator output amplitude and SHIFT to obtain a stable display, approximately 5 cm in amplitude, positioned about the centre of the graticule, the whole of the positive edge being visible and starting at approximately 0.3 cm from the start of the trace.

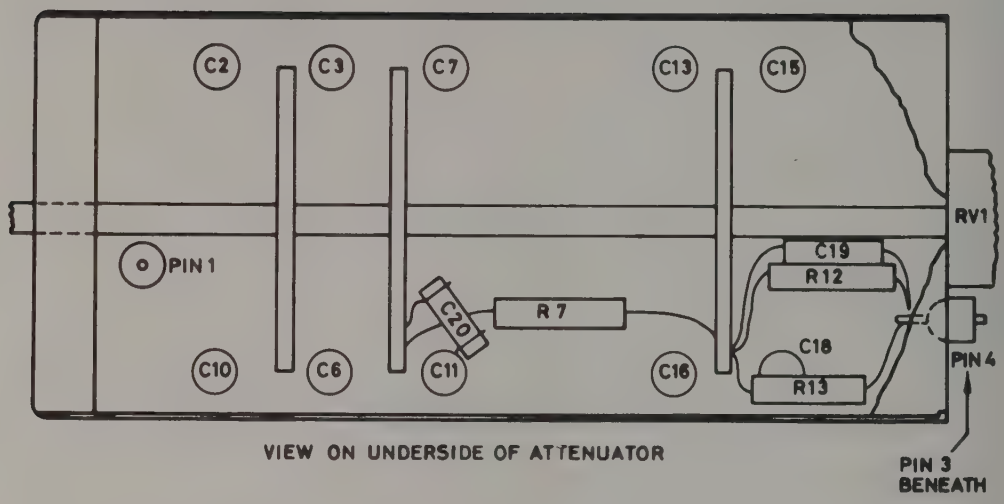
(d) Adjust 3C6 (3C20), 3C10 (3C24) and 4C2 so that any overshoot on the waveform is less than 2.5% and any ring is less than 1.5%.

NOTE: To obtain optimum pulse response between Channel 1 and Channel 2, it may be necessary to set 4C2 at a compromise adjustment.

(e) Disconnect the termination pad and fast pulse generator.

5.5 PACKAGING FOR RESHIPMENT

In the event of the equipment being returned for servicing it should be packed in the original shipping carton and packing material. If this is not available wrap the instrument in heavy paper or plastic and place in a rigid outer box of wood, fibreboard or very strong corrugated cardboard. Use ample soft packing to prevent movement. Provide additional support for projecting parts to relieve these of unnecessary shock. Close the carton securely and seal with durable tape. Mark the shipping container FRAGILE to ensure careful handling.



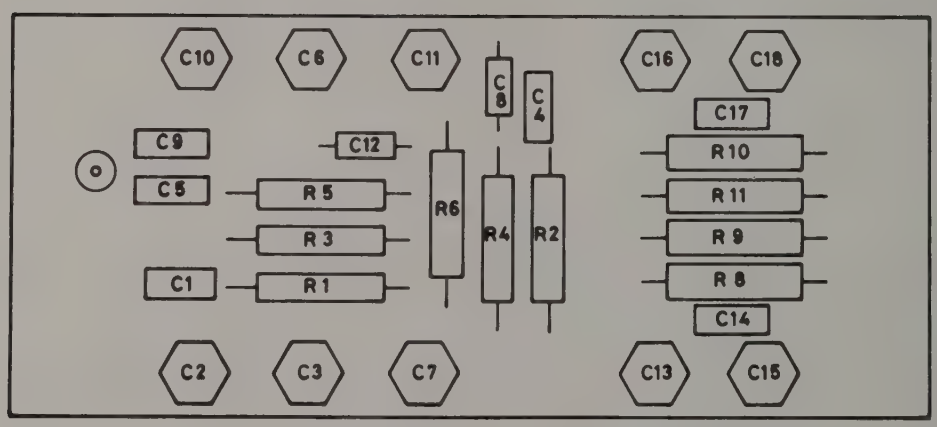


Fig. 5.6 Attenuators X5 and X6 - Component Layout

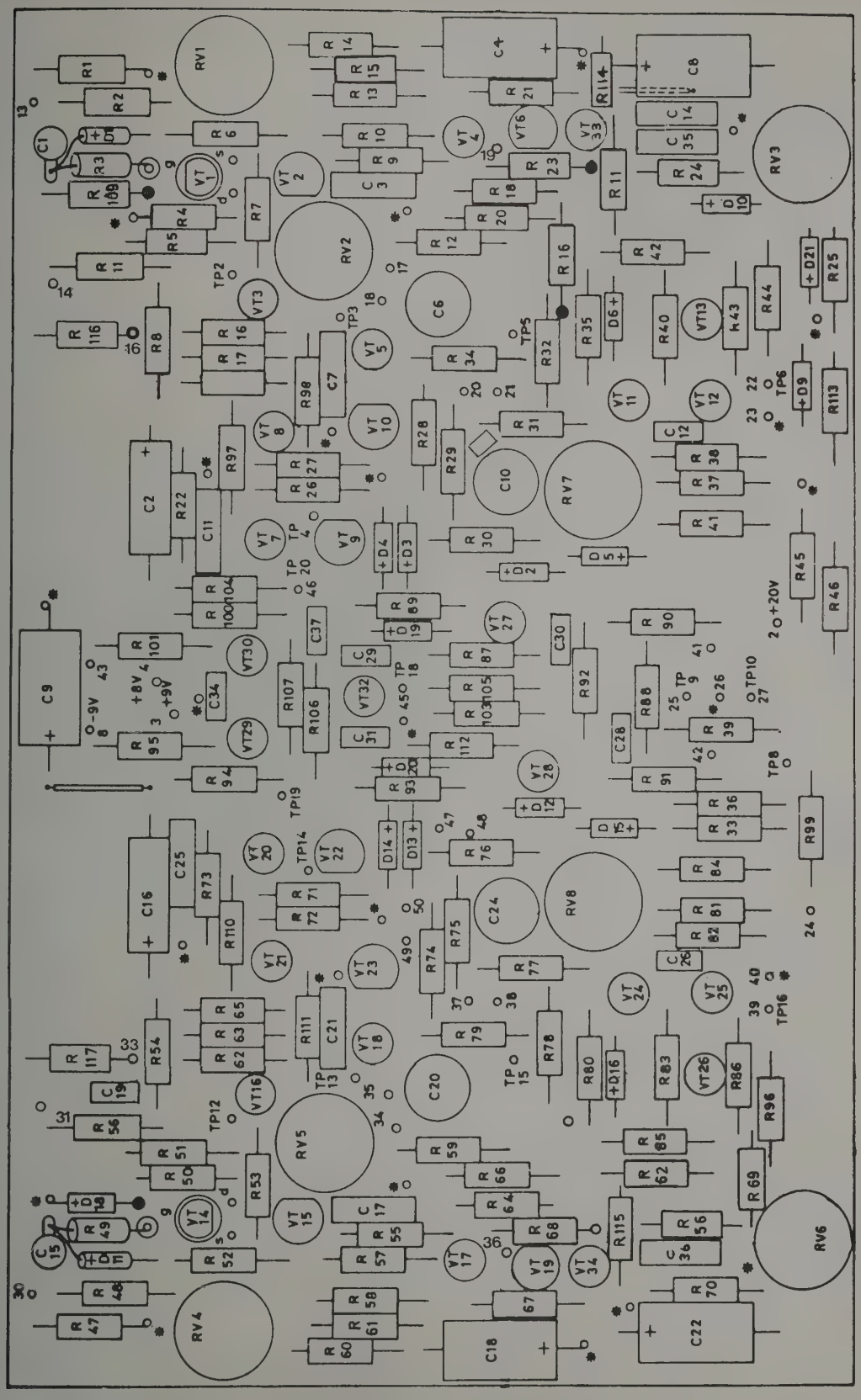


Fig. 5.7 Y-Amplifier X3 - Component Layout

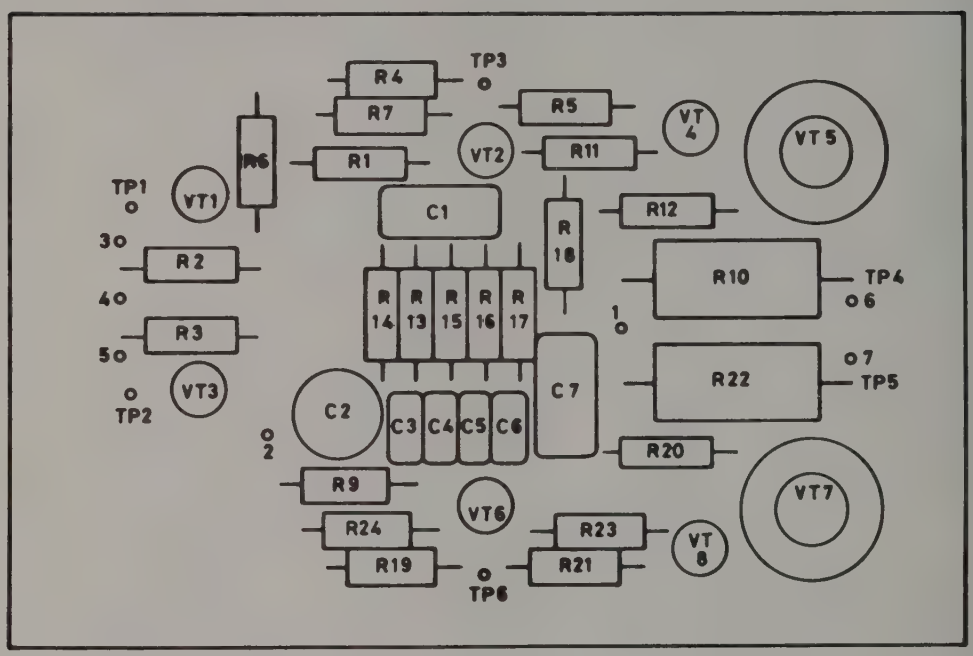


Fig. 5.8 Y Output Amplifier X4 - Component Layout

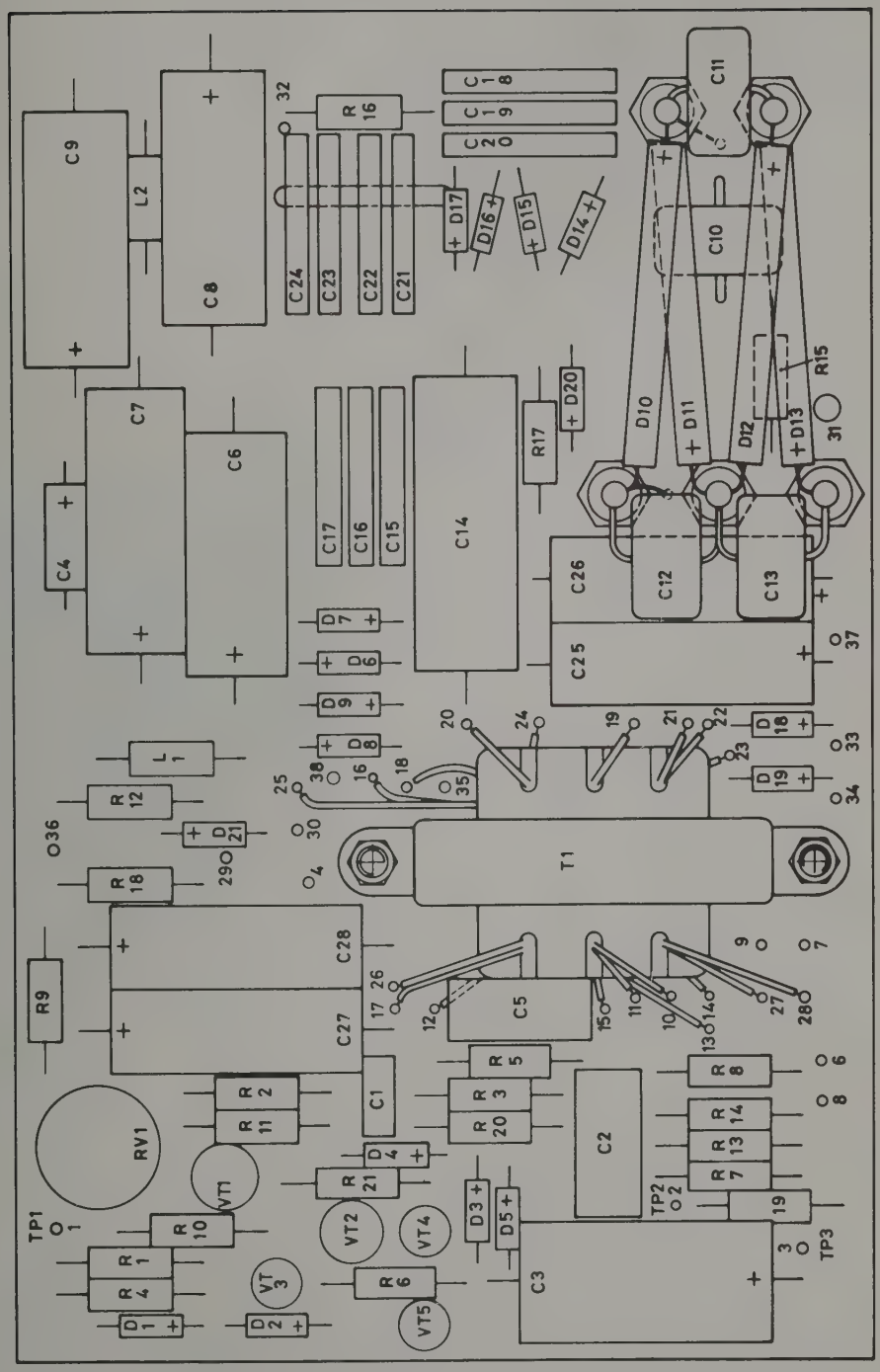


Fig. 5.9 Power Supply Unit X1 - Component Layout

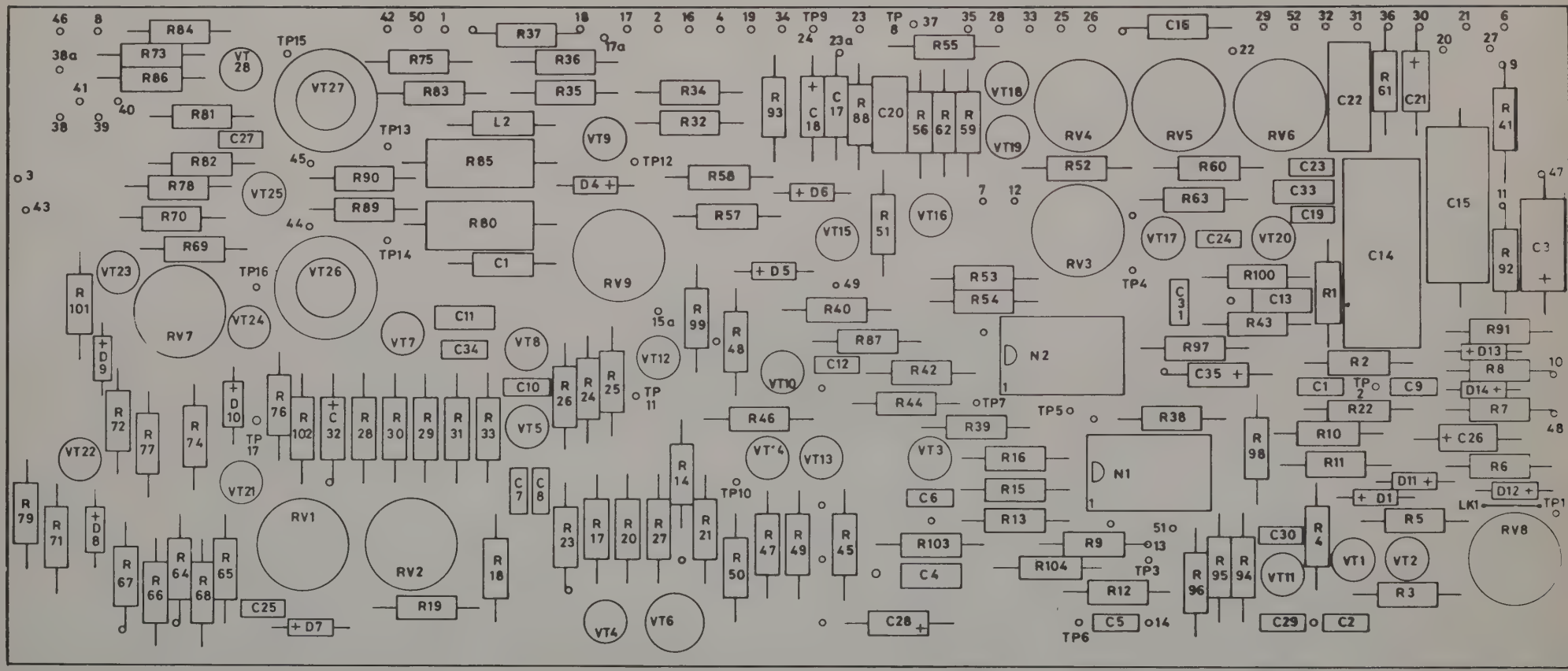
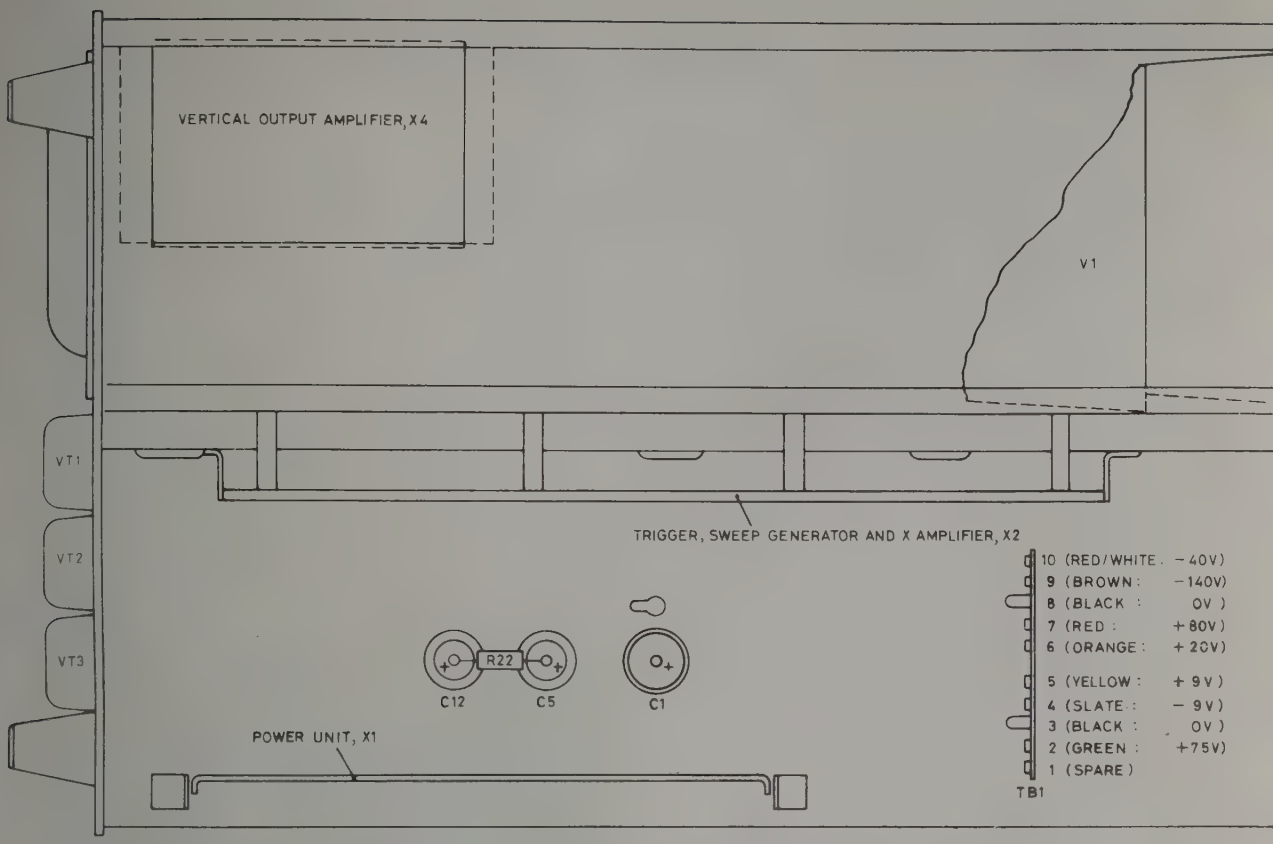
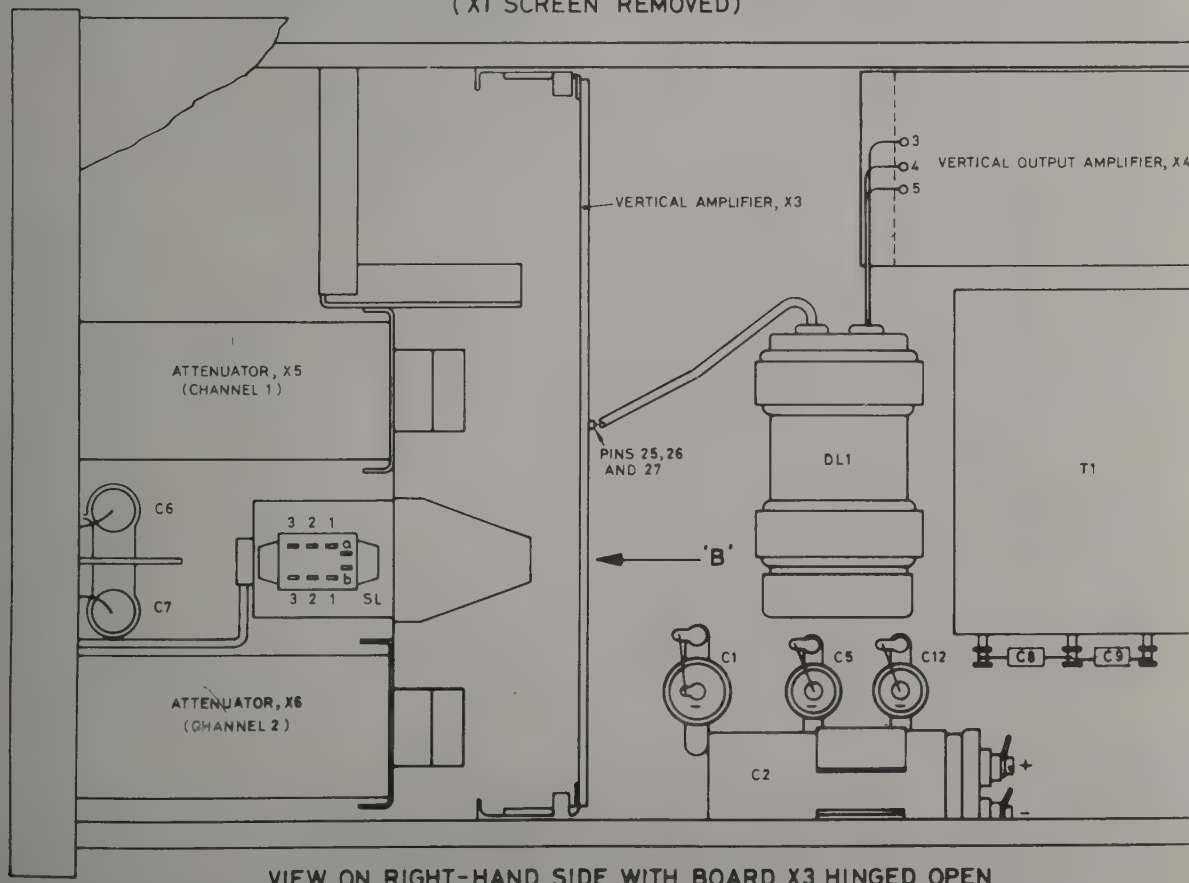


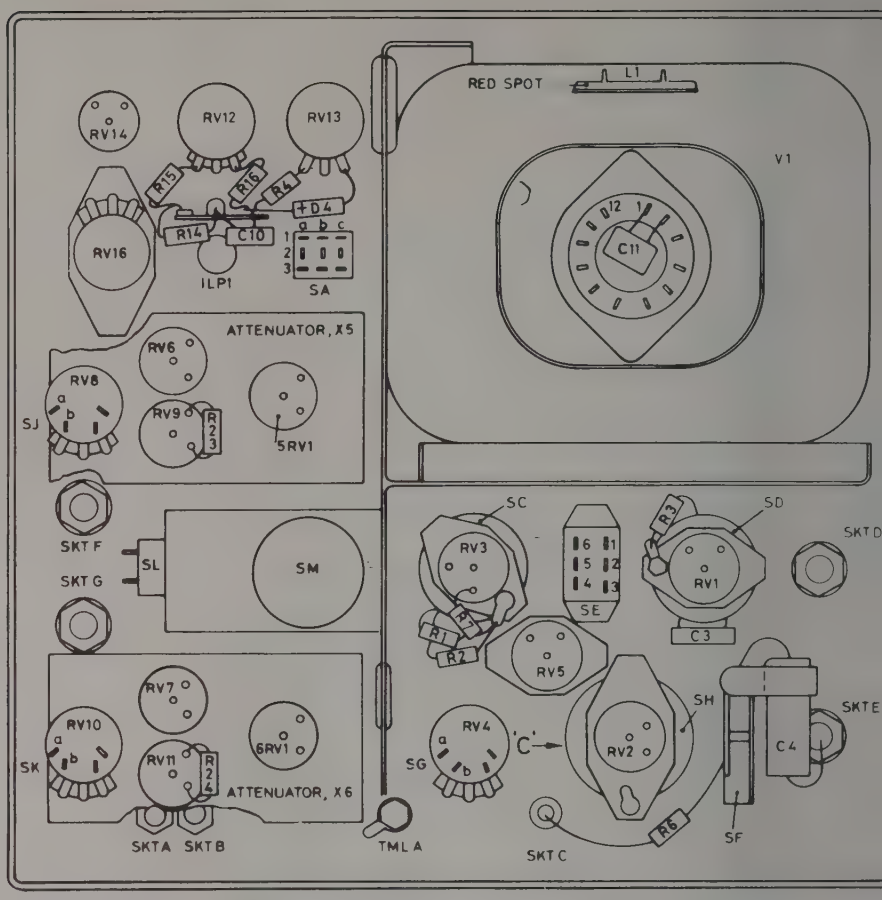
Fig. 5.10 Trigger and Sweep Generator Component Layout



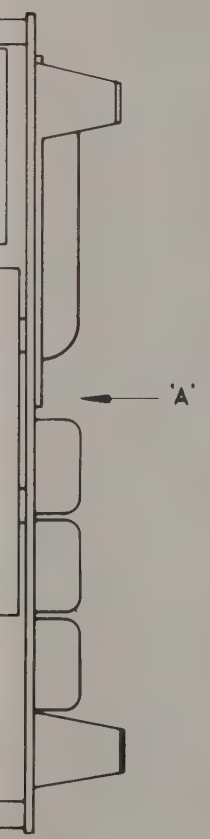
VIEW ON LEFT-HAND SIDE WITH BOARDS X1 AND X2 HINGED OPEN
(X1 SCREEN REMOVED)

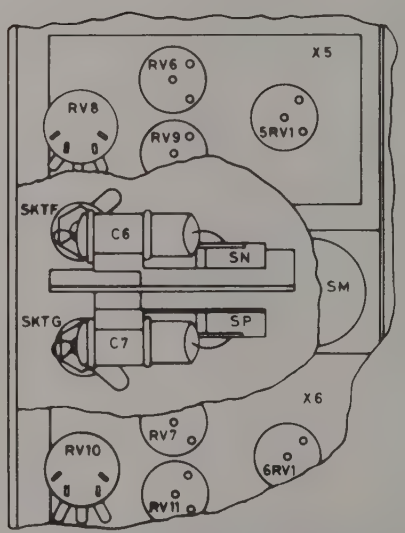


VIEW ON RIGHT-HAND SIDE WITH BOARD X3 HINGED OPEN

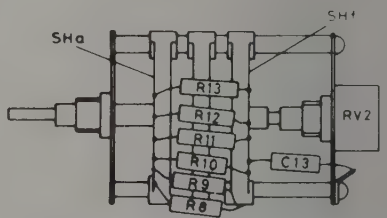


SCRAP VIEW ON ARROW 'A' SHOWING REAR OF C.R.T. AND FRONT PANE
(OMITTING C6, C7, SN AND SP)





SCRAP VIEW ON ARROW 'B'
SHOWING C6, C7, SN AND SP



SCRAP VIEW ON ARROW 'C' SHOWIN
COMPONENTS MOUNTED ON SH

Fig. 5.11 TF 2204 Oscilloscope - Component Layout

Chapter 6

Replaceable parts

6.1 INTRODUCTION

This section lists the replaceable parts in alphanumerical order of circuit references, sub-divided into six sections in the order shown below.

TF2204 18 MHz Oscilloscope Main Assembly

X1 Power Unit
X2 Trigger, Sweep Generator and X Amplifier
X3 Vertical Amplifier
X4 Vertical Output Amplifier
X5 Attenuator (Channel 1)
X6 Attenuator (Channel 2)

The following abbreviations are used in the parts list –

C	capacitor	R	resistor
D	diode	RV	variable resistor
DL	delay line	S	switch
FS	fuse	SKT	socket
ILP	indicator lamp	T	transformer
L	inductor	TML	terminal
N	integrated circuit	V	cathode ray tube
PL	plug	VT	transistor

6.2 ORDERING

When ordering replacement or spare parts, address the order to our Service Division (for address see rear cover) or nearest representative. Please specify the following information for each part required.

(i) Type and serial number of instruments.

(ii) Circuit reference number (preceded by section number e.g. X1/C5).

(iii) Description

(iv) M.I. part number (preceded by FPP).

If a part is not listed, state its function location and description when ordering.

Spares supplied against M.I. part numbers are electrically interchangeable with those originally fitted, but may not always be identical.

6.3 PARTS LIST

Circuit Reference	Description	Manufacturer/Reference	M.I. Code No. FPP/
TF 2204. 18 MHz OSCILLOSCOPE MAIN ASSEMBLY			
Circuit Sub-Assemblies			
X1		Power Unit	D60269
X2		Trigger, Sweep Generator and X Amplifier	B60272
X3		Vertical Amplifier	B60275
X4		Vertical Output Amplifier	60282
X5		Attenuator (Channel 1)	B60258
X6		Attenuator (Channel 2)	B60258
Capacitors			
C1	16μF +100% -20% 350V	Hunts JE405	CS30495
C2	4700μF +50% -10% 40V	Mullard 106/17472	CS30451
C3	0.01μF 2kV	Erie CP1/K6994	CS30186
C4	0.1μF ±25% 600V	Plessey TCC 436/1/77530	CS30167
C5	50μF +100% -20% 100V	Plessey 50/12179	CS30496
C6	0.1μF ±25% 600V	Plessey TCC 436/1/77530/590	CS30167
C7	0.1μF ±25% 600V	Plessey TCC 436/1/77530/590	CS30167
C8	0.01μF ±20% 250V	Mullard C280AE/P10K	CS30175
C9	1000pF ±20% 500V	Erie 831/K350081	CS30177
C10	0.03μF +80% -10% 1.5kV	Erie CP5/K800011	CS30452
C11	0.1μF ±20% 250V	Mullard C280AE/P10K	CS30166
C12	50μF +100% -20% 100V	Plessey 50/12179	CS30496
C13	25μF +50% -10% 6.4V	Mullard C426AR/C25	CS30477
Diodes			
D1	1S410	Texas 1S410	BS2563
D2	1S410	Texas 1S410	BS2563
D3	1S410	Texas 1S410	BS2563
D4	1S3068	Texas 1S3068	BS2703
Delay Lines			
DL1	180 ns	S.E.L. D60262/01	LS16771
Fuses			
FS1	1A 115V	Beswick TDC123	RS23087
	500mA 230V	Beswick TDC123	RS23084
FS2	2A	Beswick TDC123	RS23093
Indicator Lamps			
ILP1		Neon lamp 115V Arcolectric Switches SL162 Red	JS14068
Inductors			
L1		Coil (Part of tube screen)	
Plugs			
PLA		Plug 3 pin Bulgin P429 Socket 3 pin for PLA Bulgin P430/SE } Pair: Bulgin P360/SE	AS0289 AS1403

Circuit Reference	Description	Manufacturer/Reference	M.I. Code No. FPP/
Resistors			
R1	1MΩ ±10% ½W	Dubilier BTT	DS6248
R2	47kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32360
R3	470Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32127
R4	68kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32371
R5	Not used		
R6	4.7kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32359
R7	4.7kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32359
R8	2.4MΩ ±1%	Welwyn 4014 150 ppm/°C	DS32389
R9	1.2MΩ ±1%	Welwyn 4014 150 ppm/°C	DS32388
R10	480kΩ ±1%	Welwyn 4014 150 ppm/°C	DS32390
R11	240kΩ ±1%	Welwyn 4014 150 ppm/°C	DS32117
R12	120kΩ ±1%	Welwyn 4014 150 ppm/°C	DS3205
R13	48kΩ ±1%	—	DS32391
R14	1MΩ ±10% ½W	Dubilier BTT	DS6248
R15	820kΩ ±10% ½W	Dubilier BTT	DS6233
R16	470kΩ ±10% ½W	Dubilier BTT	DS6192
R17	Not used		
R18	Not used		
R19	Not used		
R20	Not used		
R21	Not used		
R22	1kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7479
R23	100Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32361
R24	100Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32361
R30(2204/1)	12Ω ±5%	Radio spares	DS33233
R31(2204/1)	82Ω ±10% 1W	Dubilier BTA	DS5457
Variable Resistors			
RV1	4.7kΩ ±20%	Plessey Type M Linear	FS10360
RV2	4.7kΩ ± 20%	Plessey Type M Linear	FS10360
RV3	4.7kΩ ±20%	Plessey Type M Linear	FS10360
RV4+SG	4.7kΩ ±20%	S.E.L. C60284/01 Linear (A.B. Electronics Ltd)	FS10367
RV5	4.7kΩ ±20%	Plessey Type M Linear	FS10360
RV6	4.7kΩ ±20%	Plessey Type M Linear	FS10360
RV7	4.7kΩ ±20%	Plessey Type M Linear	FS10360
RV8+SJ	1kΩ ±20%	S.E.L. C60337/01 Linear (AB Electronics Ltd)	FS10368
RV9	100Ω ±20%	Plessey Type M Linear	FS10362
RV10+SK	1kΩ ±20%	S.E.L. C60337/01 Linear	FS10368
RV11	1kΩ ±20%	Plessey Type M Linear	FS10362
RV12	1MΩ ±20%	S.E.L. C60263/02 Linear	FS10337
RV13	1MΩ ±20%	(AB Electronics Ltd)	FS10337
RV14	220kΩ ±20%	Plessey Type M Linear	FS10361
RV15	Not used		
RV16	5kΩ ±20%	Colvern CLR1189/9S/5K	FS10363
Switches			
SA	3p 2w	Fujisoku MST3050	QS22237
SB	2p 2w Slider	Switchcraft Inc. 46256 LF	QS22235
SC	1p 5w Rotary		QS22239

Circuit Reference	Description	Manufacturer/Reference	M.I. Code No. FPP/
Switches (cont)			
SD	4p 3w Rotary		D60264
SE	2p 2w Slider	Aerial Pressings RA2302	QS22188
SF	3p 3w Rotary		D60338
SG	1p 1w	(Part of RV4)	--
SH	6p 21w Rotary	S.E.L. D60266	QS22242
SJ	1p 1w	(Part of RV8)	--
SK	1p 1w	(Part of RV10)	--
SL	2p 2w Slider	Aerial Pressings RA2302	QS22188
SM	4p 5w Rotary	S.E.L. D60267	QS22240
SN	1p 3w Lever		D60289
SP	1p 3w Lever		D60289
SR (TF2204/1)	4p 3w Rotary	Radio Spares	QS22282
Sockets			
SKTA	Black	Belling Lee L1737	AS1418
SKTB	Black	Belling Lee L1737	AS1418
SKTC	Black	Belling Lee L1737	AS1418
SKTD		Greenpar GE35027 or Randall Ltd. UG1094 B/U	AS104 or AS1465
SKTE		Greenpar GE35027 or Randall Ltd. UG1094 B/U	AS104 or AS1465
SKTF		Greenpar GE35027 or Randall Ltd. UG1094 B/U	AS104 or AS1465
SKTG		Greenpar GE35027 or Randall Ltd. UG1094 B/U	AS104 or AS1465
SKTH	3 pin	Bulgin SA2404 Plug 3 pin for SKTH } Pair: Bulgin P561 Bulgin SA2404	AS1461 AS0504
Transformers			
T1		Transformer, power	D60281
Terminals			
TMLA		Terminal (ground) Belling Lee L1568/E	AS1462
Cathode Ray Tube (And Assemblies)			
V1		MO Valve Co 1424A/G1	WS28591
--		Tube and screen assembly	B60236
--		Tube screen (includes L1)	B60235
Transistors			
VT1		RCA 2N3055	BS2352
VT2		RCA 2N3055	BS2352
VT3		RCA 2N3055	BS2352

Circuit Reference	Description	Manufacturer/Reference	M.I. Code No. FPP/
X1 POWER UNIT (When ordering precede circuit reference X1)			
Capacitors			
C1	0.1μF ±20% 250V	Mullard C280AE/P100K	CS30166
C2	0.22μF ±20% 250V	Mullard C280AE/P220K	CS40489
C3	400μF +50% -20% 25V	Mullard C437AR/F400	CS30468
C4	10μF +50% -20% 16V	Mullard C426AR/E10	CS30176
C5	0.22μF ±20% 250V	Mullard C280AE/P220K	CS40489
C6	400μF +50% -10% 16V	Mullard C437AR/E400	CS30184
C7	400μF +50% -10% 16V	Mullard C437AR/E400	CS30184
C8	400μF +50% -10% 16V	Mullard C437AR/E400	CS30184
C9	400μF +50% -10% 16V	Mullard C437AR/E400	CS30184
C10	1000pF +50% -10% 8kV	Erie CHV417/K600041	CS30221
C11	1000pF +50% -10% 8kV	Erie CHV417/K600041	CS30221
C12	0.01μF 2kV		CS30186
C13	0.01μF 2kV		CS30186
C14	0.1μF ±25% 600V	TCC D753/9	CS30167
C15	0.03μF +80% -20% 1.5kV	Erie CP5/K800011	CS30452
C16	0.03μF +80% -20% 1.5kV	Erie CP5/K800011	CS30452
C17	0.03μF +80% -20% 1.5kV	Erie CP5/K800011	CS30452
C18	0.03μF +80% -20% 1.5kV	Erie CP5/K800011	CS30452
C19	0.03μF +80% -20% 1.5kV	Erie CP5/K800011	CS30452
C20	0.03μF +80% -20% 1.5kV	Erie CP5/K800011	CS30452
C21	0.03μF +80% -20% 1.5kV	Erie CP5/K800011	CS30452
C22	0.03μF +80% -20% 1.5kV	Erie CP5/K800011	CS30452
C23	0.03μF +80% -20% 1.5kV	Erie CP5 K800011	CS30452
C24	0.03μF +80% -20% 1.5kV	Erie CP5/K800011	CS30452
C25	64μF +50% -10% 64V	Mullard C437AR/H64	CS30389
C26	64μF +50% -10% 64V	Mullard C437AR/H64	CS30389
C27	160μF +50% -10% 25V	Mullard C437AR/F160	CS30091
C28	160μF +50% -10% 25V	Mullard C437AR/F160	CS30091
Diodes			
D1	1N4148	STC 1N4148	BS2542
D2	1N4148	STC 1N4148	BS2542
D3	BYX36/150	Mullard BYX36/150	BS2528
D4	BZY88/C5V6	Mullard BZY88/C5V6	BS2623
D5	BYX36/150	Mullard BYX36/150	BS2528
D6	BYX36/150	Mullard BYX36/150	BS2528
D7	BYX36/150	Mullard BYX36/150	BS2528
D8	BYX36/150	Mullard BYX36/150	BS2528
D9	BYX36/150	Mullard BYX36/150	BS2528
D10	K83/60D	STC K83/60D	BS2706
D11	K83/60D	STC K83/60D	BS2706
D12	K83/60D	STC K83/60D	BS2706
D13	K83/60D	STC K83/60D	BS2706
D14	BYX10	Mullard BYX10	BS2522
D15	BYX10	Mullard BYX10	BS2522
D16	BYX10	Mullard BYX10	BS2522
D17	BYX10	Mullard BYX10	BS2522
D18	BYX36/300	Mullard BYX36/300	BS2707
D19	BYX36/300	Mullard BYX36/300	BS2707
D20	BYX36/150	Mullard BYX36/150	BS2528
D21	BYX36/150	Mullard BYX36/150	BS2528

Circuit Reference	Description	Manufacturer/Reference	M.I. Code No. FPP/
Inductors			
L1	33μF ±10%	H.F. Choke Painton 58/10/0014/10	ES8356
L2	33μF ±10%	H.F. Choke Painton 58/10/0014/10	ES8356
Resistors			
R1	33Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32386
R2	10kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7526
R3	27kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32376
R4	330Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32128
R5	6.8kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32368
R6	10kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7526
R7	1.8kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32375
R8	33Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32386
R9	10.1kΩ ±1%	Welwyn 4014 150 ppm/°C	DS30269
R10	2.7kΩ ±1%	Welwyn 4014 150 ppm/°C	DS32395
R11	390Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32126
R12	10kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7526
R13	1.8kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32375
R14	33Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32386
R15	33kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32370
R16	5.6kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7480
R17	100Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32361
R18	15Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32394
R19	3.3kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32362
R20	1.8kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32375
R21	2.7kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32132
Variable Resistors			
RV1	1kΩ ±20% ½W	Plessey Type MP/PC Linear	FS10299
Transformers			
T1		Transformer	C60286
Transistors			
VT1	BFY51	Mullard BFY51	BS2533
VT2	BFY51	Mullard BFY51	BS2533
VT3	BCY72	Mullard BCY72	BS2519
VT4	BCY72	Mullard BCY72	BS2519
VT5	BCY72	Mullard BCY72	BS2519
X2 TRIGGER, SWEEP GENERATOR AND X AMPLIFIER (When ordering prefix circuit reference X2)			
Capacitors			
C1	270pF ±20% 500V	Erie 831/N4700	CS30458
C2	0.01μF +80% -20% 750V	Erie 801/K800011	CS30272
C3	125μF +50% -10% 10V	Mullard C426AR/D125	CS30455
C4	0.1μF ±20% 250V	Mullard C280AE/P100K	CS30166
C5	33pF ±20% 500V	Erie 831/N1500	CS30247
C6	47pF ±20% 500V	Erie 831/N1500	CS30361
C7	47pF ±20% 500V	Erie 831/N1500	CS30361
C8	100pF ±20% 500V	Erie 831/N3300	CS30218

Circuit Reference	Description	Manufacturer/Reference	M.I. Code No.† FPP/
Capacitors (cont)			
C9	180pF ±20% 500V	Erie 831/N4200	CS30473
C10	2700pF ±20% 500V	Erie 831/K7004	CS30459
C11	0.1μF ±20% 100V	STC PMA/0.1/M100	CS30460
C12	47pF ±20% 500V	Erie 831/N1500	CS30361
C13	0.1μF ±20% 250V	Mullard C280AE/P100K	CS30166
C14	4.7μF ±20% 100V	STC PMA/4.7/M100	CS30453
C15	0.047μF ±1% 125V	Mullard C295AA/D47K	CS30476
C16	430pF ±5% 160V	Suflex HS10/E	CS30474
C17	22pF ±5% 160V	Suflex HS10/D	CS30456
C18	10μF +50% -10% 16V	Mullard C426AR/E10	CS30176
C19	470pF ±20% 500V	Erie 831/K120051	CS30449
C20	0.1μF ±20% 250V	Mullard C280AE/P100K	CS30166
C21	2.5μF +50% -10% 64V	Mullard C426AR/H2.5	CS30217
C22	0.22μF ±20% 250V	Mullard C280AE/P220K	CS30489
C23	2200pF ±20% 500V	Erie 831/K7004	CS30461
C24	33pF ±20% 500V	Erie 831/N1500	CS30247
C25	1500pF ±25% 500V	Erie 831/K350081	CS30168
C26	12.5μF +50% -10% 25V	Mullard C426AR/F12.5	CS30475
C27	47μF ±20% 500V	Erie 831/N1500	CS30361
C28	10μF +50% -10% 16V	Mullard C426AR/E10	CS30176
C29	0.01μF +80% -10% 750V	Erie 831/K800011	CS30272
C30	680pF ±20% 500V	Erie 831/K350081	CS30494
C31	470pF ±20% 500V	Erie 831/K120051	CS30449
C32	12.5μF +50% -10% 25V	Mullard C426AR/F12.5	CS30475
C33	0.01μF ±20% 250V	Mullard C280AE/P10K	CS30175
C34	470pF ±20% 500V	Erie 831/K120051	CS30449
C35	10μF +50% -10% 16V	MullardC426AR/E10	CS30176
Diodes			
D1	1N4148	STC 1N4148	BS2542
D2	Not used		
D3	Not Used		
D4	1N4148	STC 1N4148	BS2542
D5	1N4148	STC 1N4148	BS2542
C6	BZY88/C6V2	Mullard BZY88/C6V2	BS2525
D7	1N4148	STC 1N4148	BS2542
D8	1N4148	STC 1N4148	BS2542
D9	1N4148	STC 1N4148	BS2542
D10	1N4148	STC 1N4148	BS2542
D11	1N4148	STC 1N4148	BS2542
D13	1N4148	STC 1N4148	BS2542
D14	1N4148	STC 1N4148	BS2542
Inductors			
L1	47μH ±10%	H.F. Choke: Painton 58/10/0021/10 Type C12	ES8372
L2	47μH ±10%	H.F. Choke: Painton 58/10/0021/10 Type C12	ES8372
Integrated Circuits			
N1	SN72710N	Texas SN72710N	BS2705
N2	SN7400N	Texas SN7400N or Mullard FJH131	BS2550

Circuit Reference	Description	Reference/Manufacturer	M.I. Code No. FPP/
Resistors			
R1	1MΩ ±10% ½W	Dubilier BTT	DS6248
R2	47kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32360
R3	2.2kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32131
R4	100Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32361
R5	560Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32383
R6	270Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32365
R7	680Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32358
R8	330Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32128
R9	5.6kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7480
R10	680Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32358
R11	680Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32358
R12	27kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32376
R13	3.3kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32362
R14	3.3kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32362
R15	3.3kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32362
R16	1.2kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7491
R17	2.2kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32131
R18	4.7kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32359
R19	1.5kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32357
R20	27kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32376
R21	2.2kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32131
R22	180Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32356
R23	68kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32371
R24	12kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7478
R25	2.2kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32131
R26	330Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32128
R27	330Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32128
R28	3.3kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32362
R29	3.3kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32362
R30	3kΩ ±1%	Welwyn 4014 150 ppm/°C	DS32378
R31	10kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7526
R32	27kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32376
R33	12kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7478
R34	10.1kΩ ±1%	Welwyn 4014 150 ppm/°C	DS32069
R35	8.9kΩ ±1%	Welwyn 4014 150 ppm/°C	DS32401
R36	900Ω ±1%	Welwyn 4014 150 ppm/°C	DS32381
R37	100Ω ±1%	Welwyn 4014 150 ppm/°C	DS32382
R38	1kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7479
R39	1.2kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7491
R40	22kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32363
R41	47Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32234
R42	680Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32358
R43	470Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32127
R44	3.3kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32362
R45	100kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32366
R46	1kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7479
R47	5.6kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7480
R48	100Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32361
R49	820Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32367
R50	2.2kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32131
R51	1kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7479
R52	470Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32127

Circuit Reference	Description	Manufacturer/Reference	M.I. Code No. FPP/
Resistors (cont)			
R53	820Ω ± 2% ½W	Electrosil TR5 orWelwyn MR5	DS32367
R54	4.7kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32359
R55	10kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7526
R56	33kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32370
R57	33kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32370
R58	33kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32370
R59	1kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7479
R60	1kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7479
R61	15kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32369
R62	47Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32234
R63	1.5kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32357
R64	1MΩ ±10% ½W	Dubilier BTT	DS6248
R65	100kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32366
R66	1.5kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32357
R67	18kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32372
R68	1kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7479
R69	1kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7479
R70	39kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32373
R71	180Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32356
R72	1.2kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7479
R73	2.7kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32132
R74	150Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32385
R75	8.2kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32374
R76	8.2kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32374
R77	1.2kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7491
R78	2.7kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32132
R79	1.8kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32375
R80	6.8kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32377
R81	1.5kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32357
R82	2.7kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32132
R83	4.7kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32359
R84	8.2kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32374
R85	6.8kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32377
R86	1.5kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32357
R87	2.2kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32131
R88	100Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32361
R89	22Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32384
R90	22Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32384
R91	270Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32365
R92	470Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32127
R93	1kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7479
R94	4.7kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32359
R95	2.2kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32131
R96	2.2kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32131
R97	1kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7479
R98	4.7kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32359
R99	100Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32361
R100	100Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32361
R101	3.3kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32362
R102	150Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32385
R103	47kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32360
R105	47kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32360

Circuit Reference	Description	Manufacturer/Reference	M.I. Code No. FPP/
Variable Resistors			
RV1	1kΩ ±20% ½W	Plessey Type MP/PC Linear	FS10299
RV2	1kΩ ±20% ½W	Plessey Type MP/PC Linear	FS10299
RV3	470Ω ±20% ½W	Plessey Type MP/PC Linear	FS10297
RV4	22kΩ ±20% ½W	Plessey Type MP/PC Linear	FS10239
RV5	22kΩ ±20% ½W	Plessey Type MP/PC Linear	FS10239
RV6	22kΩ ±20% ½W	Plessey Type MP/PC Linear	FS10239
RV7	470Ω ±20% ½W	Plessey Type MP/PC Linear	FS10297
RV8	22kΩ ±20% ½W	Plessey Type MP/PC Linear	FS10239
RV9	220kΩ ±20% ½W	Plessey Type MP/PC Linear	FS10364
Transistors			
VT1	2N3819	Texas 2N3819	BS2600
VT2	TIS50	Texas TIS50	BS2554
VT3	BSX19	Mullard BSX19	BS2622
VT4	BCY72	Mullard BCY72	BS2519
VT5	ZTX504L	Ferranti ZTX504L	BS2556
VT6	BF178	Mullard BF178	BS2561
VT7	BC108	Mullard BC108	BS2518
VT8	BC108	Mullard BC108	BS2518
VT9	BC108	Mullard BC108	BS2518
VT10	BSX19	Mullard BSX19	BS2622
VT11	BSX19	Mullard BSX19	BS2622
VT12	BSX19	Mullard BSX19	BS2622
VT13	BSX19	Mullard BSX19	BS2622
VT14	BSX19	Mullard BSX19	BS2622
VT15	2N3819	Texas 2N3819	BS2600
VT16	BC108	Mullard BC108	BS2518
VT17	BC108	Mullard BC108	BS2518
VT18	BC108	Mullard BC108	BS2518
VT19	BCY72	Mullard BCY72	BS2519
VT20	BSX19	Mullard BSX19	BS2622
VT21	2N3819	Texas 2N3819	BS2600
VT22	BCY72	Mullard BCY72	BS2519
VT23	ZTX504L	Ferranti ZTX504L	BS2556
VT24	ZTX504L	Ferranti ZTX504L	BS2556
VT25	BC108	Mullard BC108	BS2518
VT26	BF178	Mullard BF178	BS2561
VT27	BF178	Mullard BF178	BS2561
VT28	BC108	Mullard BC108	BS2518

X3 VERTICAL AMPLIFIER (When ordering prefix circuit reference X3)

Capacitors			
C1	0.8pF-7pF	Mullard C004AE/6E	CS30192
C2	64μF +50% -10% 10V	Mullard C426AR/D64	CS4745
C3	0.01μF +80% -20% 250V	Erie 801/K800011	CS30381
C4	200μF +50% -10% 10V	Mullard C426AR/D200	CS30229
C5	Not used		
C6	4pF-20pF 250V	Steatite 10S/TRIKO/06	CS30196
C7	0.1μF ±20% 250V	Mullard C280AE/P100K	CS30166
C8	200μF ±50% -10% 10V	Mullard C426AR/D200	CS30229
C9	200μF +50% -10% 10V	Mullard C426AR/D200	CS30229

Circuit Reference	Description	Manufacturer/Reference	M.I. Code No. FPP/
Capacitors (cont)			
C10	10pF-60pF 250V	Steatite 10S/TRIKO/06	CS30191
C11	0.1μF ±20% 250V	Mullard C280AE/P100K	CS30166
C12	39pF ±20% 500V	Erie 831/N1500	CS30493a
C13	Not used		
C14	0.1μF ±20% 250V	Mullard C280AE/P100K	CS30166
C15	0.8pF-7pF	Mullard C004EA/6E	CS30192
C16	64μF +50% -10% 10V	Mullard C426AR/D64	CS4745
C17	0.01μF +80% -20% 250V	Erie 801/K800011	CS30381
C18	200μF +50% -10% 10V	Mullard C426AR/D200	CS30229
C19	0.01μF +80% -20% 250V	Erie 801/K800011	CS30381
C20	4pF-20pF 250V	Steatite 10S/TRIKO/06	CS30196
C21	0.1μF ±20% 250V	Mullard C280AE/P100K	CS30166
C22	200μF +50% -10% 10V	Mullard C426AR/D200	CS30229
C23	Not used		
C24	10pF-60pF 250V	Steatite 10S/TRIKO/06	CS30191
C25	0.1μF ±20% 250V	Mullard C280AE/P100K	CS30166
C26	39pF ±20% 500V	Erie 831/N1500	CS30493
C27	Not used		
C28	15pF ±20% 500V	Erie 831/N750	CS30347
C29	15pF ±20% 500V	Erie 831/N750	CS30347
C30	15pF ±20% 500V	Erie 831/N750	CS30347
C31	15pF ±20% 500V	Erie 831/N750	CS30347
C32	Not used		
C33	Not used		
C34	1500pF ±20% 500V	Erie 831/K350081	CS30168
C35	0.1μF ±20% 250V	Mullard C280AE/P100K	CS30166
C36	0.1μF ±20% 250V	Mullard C280AE/P100K	CS30166
C37	47pF ±20% 500V	Erie 831/N1500	CS30361
Diodes			
D1	BS2524	Ferranti ZS152	BS2524
D2	1N4148	STC 1N4148	BS2542
D3	1N4148	STC 1N4148	BS2542
D4	1N4148	STC 1N4148	BS2542
D5	1N4148	STC 1N4148	BS2542
D6	BZY88/C5V6	Mullard BZY88/C5V6	BS2623
D7	Not used		
D8	Not used		
D9	BZY88/C6V8	Mullard BZY88/C6V8	BS2627
D10	BZY88/C8V2	Mullard BZY88/C8V2	BS2624
D11	ZS 152	Ferranti ZS152	BS2524
D12	1N4148	STC 1N4148	BS2542
D13	1N4148	STC 1N4148	BS2542
D14	1N4148	STC 1N4148	BS2542
D15	1N4148	STC 1N4148	BS2542
D16	BZY88/C5V6	Mullard BZY88/C5V6	BS2623
D17	Not used		
D18	BZY88/C5V6	Mullard BZY88/C5V6	BS2623
D19	1N4148	STC 1N4148	BS2542
D20	1N4148	STC 1N4148	BS2542
D21	BZY88/C5V6	Mullard BZY88/C5V6	BS2623

Circuit Reference	Description	Manufacturer/Reference	M.I. Code No. FPP/
Resistors			
R1	100Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32361
R2	39kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32373
R3	220Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32364
R4	15kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32440
R5	100Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32361
R6	1.8kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32375
R7	47Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32234
R8	1kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7479
R9	220Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32364
R10	470Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32127
R11	47kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32360
R12	47Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32334
R13	4.7kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32359
R14	27Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32402
R15	1.2kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7491
R16	180kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	
R17	1kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7479
R18	220Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32364
R19	150Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32385
R20	3.3kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32362
R21	100Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32361
R22	10Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7302
R23	100kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32366
R24	2.2kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32131
R25	1.8kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32375
R26	1.2kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7491
R27	1.2kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7491
R28	330Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32128
R29	47Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32234
R30	220Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32364
R31	220Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32364
R32	10kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7526
R33	82Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32397
R34	330Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32128
R35	1.2kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7491
R36	33Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32386
R37	1.2kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7491
R38	390Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32126
R39	82Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32397
R40	820Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32367
R41	1.2kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7491
R42	330Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32128
R43	3.9kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32409
R44	820Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32367
R45	470Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32127
R46	470Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32127
R47	100Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32361
R48	39kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32373
R49	220Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32364
R50	15kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32440
R51	100Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32361
R52	1.8kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32375

Circuit Reference	Description	Manufacturer/Reference	M.I. Code No. FPP/
Resistor (cont)			
R53	47Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32234
R54	1kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7479
R55	220Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32364
R56	47kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32360
R57	470Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32127
R58	4.7kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32359
R59	47Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32234
R60	27Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32402
R61	1.2kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7491
R62	180kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	
R63	1kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7479
R64	220Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32364
R65	150Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32385
R66	3.3kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32362
R67	100Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32361
R68	100kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32366
R69	2.2kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32131
R70	1.8kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32375
R71	1.2kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7491
R72	1.2kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7491
R73	10Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7302
R74	330Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32128
R75	47Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32234
R76	220Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32364
R77	220Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32364
R78	10kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7526
R79	330Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32128
R80	1.2kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7491
R81	1.2kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7491
R82	390Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32126
R83	820Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32367
R84	1.2kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7491
R85	330Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32128
R86	3.9kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32409
R87	820Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32367
R88	2.7kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32132
R89	4.7kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32359
R90	12kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7478
R91	12kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7478
R92	2.7kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32132
R93	4.7kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32359
R94	680Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32358
R95	2.7kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32132
R96	820Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32367
R97	150Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32385
R98	150Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32385
R99	10Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7302
R100	1kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7479
R101	4.7kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32359
R102	Not used		
R103	820Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32367
R104	1.5kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32357

Circuit Reference	Description	Manufacturer/Reference	M.I. Code No. FPP/
Resistors (cont)			
R105	1.5kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32357
R106	22kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32363
R107	680Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32358
R108	Not used		
R109	180Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32356
R110	150Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32385
R111	150Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32385
R112	33Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32386
R113	390Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32126
R114	47kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32360
R115	47kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32360
Variable Resistors			
RV1	47kΩ ±20% ½W	Plessey Type MP/PC Linear	FS10300
RV2	100Ω ±20% ½W	Plessey Type MP/PC Linear	FS10296
RV3	2.2kΩ ±20% ½W	Plessey Type MP/PC Linear	FS10308
RV4	47kΩ ±20% ½W	Plessey Type MP/PC Linear	FS10300
RV5	100Ω ±20% ½W	Plessey Type MP/PC Linear	FS10296
RV6	2.2kΩ ±20% ½W	Plessey Type MP/PC Linear	FS10208
RV7	22kΩ ±20% ½W	Plessey Type MP/PC Linear	FS10239
RV8	22kΩ ±20% ½W	Plessey Type MP/PC Linear	FS10239
Transistors			
VT1	2N3819	Texas 2N3819	BS2600
VT2	TIS50	Texas TIS50	BS2554
VT3	BSX19	Mullard BSX19	BS2622
VT4	BSX19	Mullard BSX19	BS2622
VT5	BSX19	Mullard BSX19	BS2622
VT6	TIS50	Texas TIS50	BS2554
VT7	BSX19	Mullard BSX19	BS2622
VT8	BSX19	Mullard BSX19	BS2622
VT9	TIS50	Texas TIS50	BS2554
VT10	TIS50	Texas TIS50	BS2554
VT11	BSX19	Mullard BSX19	BS2622
VT12	BSX19	Mullard BSX19	BS2622
VT13	BCY72	Mullard BCY72	BS2519
VT14	2N3819	Texas 2N3819	BS2600
VT15	TIS50	Texas TIS50	BS2554
VT16	BSX19	Mullard BSX19	BS2622
VT17	BSX19	Mullard BSX19	BS2622
VT18	BSX19	Mullard BSX19	BS2622
VT19	TIS50	Texas TIS50	BS2554
VT20	BSX19	Mullard BSX19	BS2622
VT21	BSX19	Mullard BSX19	BS2622
VT22	TIS50	Texas TIS50	BS2554
VT23	TIS50	Texas TIS50	BS2554
VT24	BSX19	Mullard BSX19	BS2622
VT25	BSX19	Mullard BSX19	BS2622
VT26	BCY72	Mullard BCY72	BS2519
VT27	BSX19	Mullard BSX19	BS2622
VT28	BSX19	Mullard BSX19	BS2622

Circuit Reference	Description	Manufacturer/Reference	M.I. Code No. FPP/
Transistors (cont)			
VT29	BSX19	Mullard BSX19	BS2622
VT30	BSX19	Mullard BSX19	BS2622
VT31	Not used		
VT32	BSX19	Mullard BSX19	BS2622
VT33	BC108	Mullard BC108	BS2518
VT34	BC108	Mullard BC108	BS2518

X4 VERTICAL OUTPUT AMPLIFIER (When ordering prefix circuit reference X4)

Capacitors			
C1	0.1μF ±20% 250V	Mullard C280AE/P100K	CS30166
C2	10pF-60pF 250V	Steatite 10STRIKO/06	CS30191
C3	100pF ±20% 500V	Suflex	
C4	150pF ±20% 500V	Erie 831/N3300	CS30219
C5	56pF ±20% 500V	Suflex	
C6	1000pF ±20% 500V	Erie 831/K350081	CS30177
C7	0.1μF ±20% 250V	Mullard C280AE/P100K	CS30166
Resistors			
R1	470Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32127
R2	82Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32397
R3	82Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32397
R4	1kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7479
R5	100Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32126
R6	1kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7479
R7	390Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32126
R8	Not used		
R9	470Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32127
R10	1kΩ ±5%	Welwyn F75	DS32399
R11	120Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32398
R12	150Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32385
R13	68Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32410
R14	150Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32385
R15	1kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7479
R16	10Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7302
R17	6.8kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32368
R18	8.2kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32374
R19	1kΩ ±2% ½W	Electrosil TR5 or Welwyn MR5	DS7479
R20	150Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32385
R21	100Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32361
R22	1kΩ ±5%	Welwyn F75	DS32399
R23	120Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32398
R24	390Ω ±2% ½W	Electrosil TR5 or Welwyn MR5	DS32126
Transistors			
VT1	BSX19	Mullard BSX19	BS2622
VT2	BSX19	Mullard BSX19	BS2622
VT3	BSX19	Mullard BSX19	BS2622
VT4	BSX19	Mullard BSX19	BS2622
VT5	2N2218A	Mullard 2N2218A	BS2710
VT6	BSX19	Mullard BSX19	BS2622
VT7	2N2218A	Mullard 2N2218A	BS2710
VT8	BSX19	Mullard BSX19	BS2622

Circuit Reference	Description	Manufacturer/Reference	M.I. Code No. FPP/
X5 AND X6 ATTENUATOR (When ordering prefix circuit reference X5 or X6)			
Capacitors			
C1	10pF ±5% 500V	Erie 831/NPO	CS30304
C2	0.8pF-7pF	Mullard C004EA/6E	CS30192
C3	0.8pF-7pF	Mullard C004EA/6E	CS30192
C4	10pF ±5% 500V	Erie 831/NPO	CS30304
C5	10pF ±5% 500V	Erie 831/NPO	CS30304
C6	0.8pF-7pF	Mullard C004EA/6E	CS30192
C7	0.8pF-7pF	Mullard C004EA/6E	CS30192
C8	150pF ±10% 160V	Suflex HS7	CS30465
C9	10pF ±5% 500V	Erie 831/NPO	CS30304
C10	0.8pF-7pF	Mullard C004AE/6E	CS30192
C11	0.8pf 7pF	Mullard C004AE/6E	CS30192
C12	1500pF ±10% 63V	Suflex HS7	CS30466
C13	0.8pF-7pF	Mullard C004EA/6E	CS30192
C14	10pF ±5% 500V	Erie 831/NPO	CS30304
C15	0.8pF-7pF	Mullard C004EA/6E	CS30192
C16	0.8pF-7pF	Mullard C004EA/6E	CS30192
C17	2.2pF ±20% 500V	Erie 831/P100	CS30416
C18	0.8pF-7pF	Mullard C004EA/6E	CS30192
C19	1500pF ±20% 500V	Erie/K350081	CS30168
C20	1pF ±25% 750V	Erie XD	CS30467
Resistors			
R1	900kΩ ±1%	Welwyn 4014 150 ppm/°C	DS32065
R2	111kΩ ±1%	Welwyn 4014 150 ppm/°C	DS32068
R3	990kΩ ±1%	Welwyn 4014 150 ppm/°C	DS32066
R4	10.1kΩ ±1%	Welwyn 4014 150 ppm/°C	DS32069
R5	1MΩ ±1%	Welwyn 4014 150 ppm/°C	DS32067
R6	1kΩ ±1%	Welwyn 4014 150 ppm/°C	DS32070
R7	47Ω ±10% ½W	Dubilier BTT	DS5195
R8	600kΩ ±1%	Welwyn 4014 150 ppm/°C	DS32392
R9	666kΩ ±1%	Welwyn 4014 150 ppm/°C	DS32393
R10	800kΩ ±1%	Welwyn 4014 150 ppm/°C	DS32072
R11	250kΩ ±1%	Welwyn 4014 150 ppm/°C	DS32073
R12	470kΩ ±10% ½W	Dubilier BTT	DS6192
R13	1MΩ ±1%	Welwyn 4014 150 ppm/°C	DS32067
Variable Resistors			
RV1	220kΩ ±20%	Plessey Type M Linear	FS10361
Switches			
SA	4p 11w		QS22241

Chapter 7

Circuit diagrams

CIRCUIT NOTES

1. Component Values

Resistors: No suffix - ohms
k - kilohms
M - megohms
Capacitors: No Suffix - microfarads
p - picofarads

2. Voltages

These are D.C. and relative to chassis unless otherwise stated.
Waveforms and test points are printed in green.

3. Switches

Rotary switches are drawn schematically.
Wafers are shown viewed from front of switch in the extreme counterclockwise position, centre arrow indicates movement of wafer.

5. Circuit Diagrams

Fig. 7.1 18MHz Oscilloscope TF 2204 - Block Schematic Diagram
Fig. 7.2 Inter Unit Wiring (Sheet 1 and 2)
Fig. 7.3 Trigger and Sweep Generator X2 - Trigger and Calibrator Circuit Diagram
Fig. 7.4 Trigger and Sweep Generator X2 - Sweep Generator and CRT Circuit Diagram
Fig. 7.5 Trigger and Sweep Generator X2 - X Amplifier Circuit Diagram
Fig. 7.6 Attenuators X5 and X6 (Channel 1 and 2) Circuit Diagram
Fig. 7.7 Y Amplifier X3 Circuit Diagram
Fig. 7.8 Y Amplifier X3 - Mode Selector Circuit Diagram
Y Output Amplifier X4 - Circuit Diagram
Fig. 7.9 Power Supply Unit (TF 2204) Circuit Diagram
Fig. 7.10 Battery Charging Unit (TF 2204/1) Circuit Diagram